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TACTICAL FUEL AND ENERGY STRATEGY FOR THE FUTURE MODULAR FORCE

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This report provides the Department of the Army (DA) G-4 and the United States Army Combined Arms Support Command (USACASCOM), Concepts and Doctrine Directorate (CDD) with a proposed Tactical Fuel and Energy Strategy for the future Modular Force. Statements, opinions, conclusions, and recommendations in this report do not necessarily represent the official position of the DA or the USACASCOM.

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FOREWORD

This study provides the DA G-4 and USACASCOM, Concepts and Doctrine Directorate (CDD) with a Future Tactical Fuel and Energy Strategy for the future Modular Force to bridge the gap from now until the 2015-2024 timeframe. The strategy is the first step to synchronize the Army's internal efforts to reduce redundancy and leverage previous and ongoing efforts in this area. As outlined in the scope and purpose sections of Chapter 1, this strategy begins the process and reviews broad overarching concepts which will be fully expanded and detailed in a follow on effort that will provide a future tactical fuel and energy implementation plan.

The report consists of an executive summary, introduction, major sections on the Army's fuel and energy posture, future fuel and energy goal analysis, Doctrine, Organization, Training, Materiel, Leadership and Education, Personnel and Facilities (DOTMLPF) analysis, findings and recommendations, and appendices.

Appendix A provides a list of alternative fuel/energy and power source options that are emerging within the U.S. and includes a list of advantages and disadvantages for each fuel/energy option.

Appendix B provides a list and description of alternate fuel vehicles and equipment.

Appendix C provides an implementation metric matrix.

Appendix D provides a list of acronyms and abbreviations.

Appendix E provides a list of terms and definitions.

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EXECUTIVE SUMMARY

As the United States becomes more reliant on imported energy resources, there is an urgent need to examine the implications of the domestic and world energy situations on the Tactical Army, and to formulate an effective and viable path for the Army's tactical fuel and energy future. With our national energy requirement increasing annually, harvesting alternative energy sources is an absolute priority for the nation, Department of Defense (DoD), and the Army. The Army is currently working to better understand the value of energy in terms of cost and operational capability, and to modify business processes to more accurately integrate those values into decisions that affect requirements planning, acquisition, and funding priorities. The operational environment includes energy sources, energy consumption, fiscal challenges, dynamic and changing operational strategies, evolving technologies, and the opportunities to not only reduce consumption, but to diversify supply through alternative energy solutions. The use of alternative energy sources must be synchronized with efforts to reduce consumption; otherwise there is no energy savings realized, but merely a shift from one supply source to another. The Army is engaged with other federal entities and industry to adopt best business practices and technologies for conservation and alternative power development. However, a fully supported strategy is the result of requirements identification and effective resource advocacy.

Overview

This strategy maps the "way ahead" for meeting fuel and energy mandates at the tactical level from now into the 2015-2024 timeframe. It requires investment in enabling technologies as well as a greater degree of resource accountability for success. As an interim step, recommendations contained in this study and the strategy outlined will provide the Army with a baseline of how the current use of fuel and energy should evolve for fuel and energy reduction given the projected fleet of vehicles and equipment as well as anticipated demands for the 2015-2024 timeframe. These recommendations will guide the Army toward reduced petroleum-based fuel use, higher energy efficiency, and the integration of alternative energy solutions into the future Modular Force.

Defense managers and logistics planners must recognize that the Army's Tactical Fuel and Energy future is inextricably linked to the fate of the DoD and National Energy Strategies, and not harbor illusions that the Operational Army can independently develop and implement long-term solutions which fully address tactical energy challenges. The reality is that many of the issues in the fuel and energy arena are outside the control of the Army. Several actions are in the purview of the national Government to foster the ability of all groups, including the Army, to optimize their natural resource management. The Army needs to present its perspective to higher authorities and be prepared to proceed in concert with national efforts.

Petroleum-based fuels will remain as the primary component of our tactical fuel and energy picture for the future Modular Force well past 2024. However, there are a number of key evolutions on the horizon in the upcoming decade to allow for decreased dependency on petroleum-based fuels. The road ahead is interconnected in a global energy matrix stretching across our military services, the nation, and the international community. There are multiple energy solutions being worked across this global energy matrix. Some of those solutions are relevant to the military while others are not, yet all of these solutions impact overall energy requirements.

As the Army embraces new energy technologies, defense planners must ensure that requirements for operational reach and endurance capability (i.e., deployment and sustainability) are also met. The Army's mission is to fight and win our nation's wars by providing prompt, sustained land dominance across the full range of military operations and spectrum of conflict in support of combatant commanders.

The strategy for the future Modular Force for fuel and energy use must focus on key pillars. These pillars include equipment platform improvements, reduced energy requirements, increased

alternative and renewable energy usage, changing the cultural mindset, and increased national energy security.

Equipment platform improvements to improve energy efficiency are directly linked to power production and the associated power train. There are numerous potential improvements and alternatives on the horizon which may be adapted by the Army. Turbine engines currently used in the Army's rotary aircraft and armored vehicles could have petroleum-based fuel blended with coal-based alternative fuels similar to that being investigated and tested by the Air Force. Ground vehicles that run on internal combustion engines could evolve to a family of vehicles with advanced fuel efficient propulsion systems including hybrid electric powered vehicles. Power generation equipment could be modified to include solar capabilities and intelligent power distribution to reduce petroleum-based fuel consumption.

As technology changes, new opportunities to reduce energy consumption, and potentially costs, are created. Ethanol, biodiesel, hydrogen fuel cells, plasma waste-to-energy systems, and lithium-ion batteries are some of the technologies starting to evolve in the open market that may transform our vehicles, equipment, and facilities. These should all be explored in greater detail to determine if they are feasible options for incorporation by the Army. The market price of these and other alternative and renewable energy technologies, such as solar photovoltaic, wind, and geothermal, will continue to drop. The Army must aggressively seek ways to use new and improved technologies to meet its strategic energy goals, while reducing its carbon footprint and our vulnerabilities to commercial sources of supply.

The Army must continue its focus on developing and demonstrating leading edge energy initiatives that are ultimately employed for operational uses. This requires defining and meeting specific objectives/goals. Five important goals have been established which will serve as a measuring stick for evaluating results. Meeting these goals requires a strategy that combines many diversified elements. These goals are as follows:

- Reduce dependence on petroleum-based fuel.
- Reduce consumption while maintaining current tactical capabilities.
- Find alternative fuel/energy sources that are feasible and suitable, to maintain operational reach, operational endurance, and support the Warfighter in a joint and coalition operating environment.
- Reduce resources required for fuel/energy support to the tactical force.
- Establish improved fuel and energy distribution methods while maintaining safety and environmental standards.

At the core of this energy strategy is the recognition that the Army needs industry and federal partnerships to meet or exceed these Tactical Fuel and Energy goals. Implementation of the Tactical Fuel and Energy Strategy for the future Modular Force will deliver a positive return on investment and sustain our leadership in energy conservation and alternative energy.

Findings and Recommendations

This section provides a list of findings and recommendations resulting from the study effort. Discussions of findings and recommendations contained in this section have been abbreviated. Chapter 9 provides a more detailed discussion of each finding and recommendation.

Finding #1: Petroleum-based fuels will remain the Army's main power source for tactical platforms from now until the 2024 timeframe, the timeframe for this strategy, and beyond. However, alternative fuel and renewable energy options are rapidly maturing to a point where integration of several of these options are viable for tactical military operations.

There are a number of evolving and viable alternative energy options that can be further researched and developed for integration into tactical equipment platforms to supplement petroleum-based fuels and thereby decrease petroleum-based fuel requirements. The Army can stage itself through additional and increased R&D efforts to implement these alternative energy options when economics and operational imperatives allow for their incorporation. Each of these changes would require comprehensive analyses to ensure that any trade-off to alternative fuel/energy sources provide a positive return across a multitude of considerations including cost, operational feasibility, lift requirement, energy value, and maintenance impacts.

Recommendation #1: Alternative fuel and renewable energy solutions should be researched and developed on an aggressive timeline for implementation to the degree possible in the future Modular Force.

Alternative fuel and renewable energy solutions should be developed to supplement petroleum-based fuel requirements. While these can lessen the amount of petroleum-based fuels required, they will not be able to replace petroleum-based fuels by the year 2024. The degree to which alternative energy can be integrated into tactical operations is dependent on the spectrum of conflict, the maturation of the alternative energy options, and the economic feasibility of moving from the traditionally low cost of petroleum-based fuels.

Advanced hybrid electric power systems are well within the 2024 timeline for incorporation into the Modular Force. The testing and fielding of hybrid electronic architecture should continue to be pursued and implemented to the extent possible. Renewable energy resources such as solar energy and its use with power generation platforms with intelligent power form an alternative energy solution for the power platform category. The optimum solution set will continue to evolve as technology developments provide alternatives to current petroleum-based fuels.

Finding #2: Decreases in petroleum-based fuel use for power generation equipment are feasible in the near term with technology solutions that are currently available or evolving.

U.S. Army power generation equipment comprises one of the largest consumer commodities of petroleum-based fuels on the battlefield as discussed in Chapter 4 of this document. As such, any actions that can be taken to decrease the use of petroleum-based fuels in this arena will have a noticeable impact on lessening the tactical Army's overall petroleum-based fuel requirements.

Recommendation #2: Invest in the development and fielding of solar solutions and other alternative energy sources to supplement existing power generation systems and in an intelligent power program to centrally manage power-generation platforms in base camp-type locations.

Renewable energy resources are getting closer to being capable of providing a viable energy source to tactical forces. Future improvements in technology and significant price drops in fundamental solar panel components may bring solar power into the realm of operational feasibility during the time frame covered by this strategy. While solar energy cannot compete with the low price of petroleum-based fuels in our civilian sector for some time, the fully burdened cost of fuel in tactical operations may make solar energy a viable and realistic energy source in a multitude of tactical operations.

Evolving initiatives such as intelligent power open the option to more efficient use of the various power-producing platforms in such places as operating bases. Coupling renewable energy and intelligent power with reduced solar loading can even further reduce energy needs.

Finding # 3: Current tactical planning and mission execution does not consider fuel and energy conservation.

There is no institutional mindset across the Army to consider fuel/energy reduction efforts when planning for tactical operations. The “Single Fuel on the Battlefield” concept was designed to reduce the logistics footprint by reducing the multiple fuel grades transported/stored/issued at the same location. The concept was never truly implemented in practice as evidenced by the number of fuel grades currently in use on the battlefields in Iraq and Afghanistan. Although the goal of a single fuel may not be 100% achievable, a significant reduction in multiple fuel grades (gasoline and diesel fuel specifically), and the associated support footprint, could be realized resulting in significant efficiencies when transporting and storing these commodities.

Recommendation #3: The Army should institutionalize fuel/energy savings procedures and concepts across all levels. Every effort must be made to reduce the number of fuel grades required on the battlefield.

A shift in Army culture regarding energy is required and the Army must institutionalize the concept of fuel/energy savings across all levels. Army leaders at all levels must be trained to recognize or create opportunities to conserve energy and be prepared to exploit them. Where ever possible the number of fuel grades on the battlefield should be reduced in order to capitalize on efficiencies garnered by storing only one grade of fuel. Future developments may allow the predominant fuel on the battlefield to include alternative fuels and these options must be taken into consideration when developing support options. This recommendation may conflict with several others in this study to pursue alternative fuel options. In each case a thorough trade-off analysis is required to weigh the overall effect of a course of action.

Finding #4: The Army does not have an automated asset visibility tool for fuel which in turn leads to an inability to accurate reflect on-hand totals or future requirements on the battlefield.

Current asset visibility for fuel on the battlefield requires manual data collection and reporting. The ability to see the total fuel picture in the battle space in real time, combined with the ability to dynamically reallocate petroleum assets as combat operations evolve can greatly improve the efficient delivery of this scarce and critical resource. In addition to contributing to sustained operational tempo and extending operational reach, the number and frequency of fuel convoys/sorties could also be reduced, with a corresponding reduction in the vulnerability of these assets and the number of soldiers pulled from other duties to protect them. The most important part of this process is the total visibility that will be made available to commanders at all levels.

Recommendation #4: The Army should continue efforts toward field automation to allow for both asset visibility and accountability of fuel on the battlefield.

The Army must continue efforts to field an automated accountability system for fuel on the battlefield. This system would allow commanders to view near real-time information regarding fuel on-hand and consumption trends. At a higher level, this data would be used to meet forecast requirements while considering realistic on-hand totals. In total, this view of on-hand fuel assets would allow for tailored resupply focusing efforts to meet demand without building excessive stockage levels.

Finding #5: Petroleum-based fuel supply interruptions will be greater in the future as global demand increases and global supply decreases.

Our nation’s wars will continue to be waged on other continents. Extended lines of communications from our CONUS bases and less petroleum-based fuel availability in the future to meet global demands raise the probability of shortfalls in the supply of petroleum-based fuels to our fighting forces.

Recommendation #5: Increased storage requirements should be considered in OCONUS locations for our Prepositioned War Reserve Material Stocks (PWRMS) and Peacetime Operating Stocks (POS) of fuel.

Our OCONUS fuel stocks are placed at geographical locations that provide strategic fuel storage to meet wartime and peacetime requirements. As global demand for fuel increases, and petroleum-based fuel production decreases, the relative shortage poses an increasing supply risk. We can mitigate this risk by maintaining current levels of PWRMS and POS of fuel; continuing to partner with other countries to purchase and store fuel; and investing in research and development for modernizing fuel consuming vehicles and equipment and introducing alternative and renewable sources to reduce reliance on and consumption of petroleum-based fuels.

Finding #6: The Army does not have a single office designated to address all tactical fuel and energy issues to maintain the operational visibility during the global energy evolution.

The Army has recently established several levels of oversight to guide energy security issues as outlined in the Army Energy Security Implementation Strategy[1]. However, there remains no single office/point of contact designated to focus solely on tactical fuel/energy issues. This lack of a designated office results in multiple agencies/offices focusing on tactical energy efforts, but each within their specific area with limited synchronization across the Army.

Recommendation #6: The Army should consider establishing a Tactical Fuel and Energy Office to serve as the focal point and advocate for energy initiatives which support tactical deployment. This office would be charged to synchronize efforts across the Army while coordinating with the other services to ensure all efforts reflect the joint environment.

The Army should establish a single office to serve as the focal point and advocate for energy initiatives which support tactical operations. This office would serve as the primary advocate for tactical fuel/energy issues and solutions. It would be charged to synchronize efforts across the Army while coordinating with the other services to ensure all efforts reflect the joint environment.

Finding #7: Fuel specifications for military use were originally developed solely for petroleum-based fuels. Specifications are currently being updated to include alternative fuels.

Alternative fuels were not a major consideration when the original fuel specifications were established for currently fielded tactical equipment. The introduction of alternative fuels as suitable products have, and will continue to provide, a requirement to allow for their use in tactical equipment thereby requiring changes to equipment specifications. Additionally, the storage stability standards of 36 to 48 months for petroleum-based fuels may be excessive based on the inclusion of alternative fuels as acceptable substitutes.

Recommendation #7: Reevaluate all applicable fuel standards to ensure the standards are still valid for today's global conditions.

Alternative energy fuels and petroleum-based fuels should be considered together in determining necessary standards that meet our needs today. The Army should continue to evaluate alternative fuels for consumption in tactical equipment and modify equipment specifications to allow for the use of these fuels. Additionally, storage stability should be reviewed as alternative fuels are approved for use to ensure new fuels are addressed appropriately when long-term storage is a consideration.

[1] Army Energy Security Implementation Strategy. Army Security Energy Council and the Office of the Deputy Assistant Secretary of the Army for Energy and Partnerships, Washington, DC. 13 January 2009.

Chapter 1: Introduction

As this nation becomes more reliant on imported energy resources, there is an urgent need to examine the implications of the domestic and world energy situations on the Tactical Army, and to formulate an effective and viable path for the Army's tactical fuel and energy future. With our national energy requirement increasing annually, harvesting alternative energy sources is an absolute priority for the nation, the DoD, and the Army.

The Army must continually consider the short-term and long-term issues involved in developing energy strategies and solutions for its tactical deployments. To sustain its mission and ensure its capability to project and support the forces, the Army must minimize the impact of the economic and logistical energy-related problems coming in the near to mid term. This requires a transition to energy efficient systems and an investment in technologies that are effective, suitable, and sustainable in a tactical environment. These challenges require thoughtful planning and execution and integrated solutions.

The Tactical Fuel and Energy Strategy for the future Modular Force must be comprehensive and include the full spectrum of energy activities across all operational and support areas. It must address the objectives to reduce demand through conservation and efficiency, increase supply through alternative energy sources, and create a culture where energy is a consideration in every decision process, whether developing new weapons systems or procuring fuel-efficient support vehicles. At the core of this strategy is the recognition that the Army needs industry and federal partnerships to meet or exceed our energy goals. Industry brings innovation, engineering and technology, and a successful track record of managed risk to a multi-faceted energy management partnership. With the Army consuming less than one-half of one percent of the total U.S. consumption of petroleum-based fuels, it will clearly not be the driver to solutions but needs to concentrate on being able to use the solutions the market develops.

1.1 Purpose

This strategy maps the "way ahead" for meeting fuel and energy mandates at the tactical level from now into the 2015-2024 timeframe. It requires investment in enabling technologies as well as a greater degree of resource accountability for success. This strategy must be viewed as an integral part of both the national and the DoD strategy and cannot be executed in isolation as a standalone Army effort. It will be a living document and updated on a regular basis as conditions warrant responding to major changes to statute, executive order, the DoD or Army policy, or a national crisis. The strategy will synchronize the Army's internal efforts with those of the joint community to reduce redundancy and leverage previous and ongoing efforts in this area. As an interim step, recommendations contained in this study will provide the Army with a baseline of how we are currently using fuel and energy and will propose methods for energy reduction given the projected fleet of vehicles and equipment in the 2015-2024 timeframe.

The overall goal is to provide a realistic assessment of the Army's current Tactical Fuel and Energy situation and to begin to develop flexible options and recommend choices and investments that will yield a balanced strategy. At this stage in the process, this strategy is by design broad and overarching. Further details including business case analyses, detailed assessment of options with a cost/benefit analysis, and implementing instructions are scheduled to follow this effort. End state success will be measured with accurate data and analysis and by constant monitoring and evaluation of the execution of the strategy's objectives. Recommendations developed in this study will focus on the following:

- The overarching Army Tactical Fuel and Energy challenges
- Alternatives to petroleum-based fuel technology and equipment
- Demand reduction for fuel and energy
- Reduction in the numbers/types of fuel received, stored, issued, and distributed to reduce logistics footprint
- Improving fuel and energy delivery methods that will increase Soldier survivability

- Identification of fuels and energy solutions that are feasible, suitable and sustainable for the future Modular Force
- Finally, development of metrics that will serve as a gauge to measure progress in total fuel and energy reduction, as well as reduction in the tactical military's dependence on petroleum-based fuels.

1.2 Explanation of Abbreviations and Terms

Abbreviations and special terms used in this study are explained in Appendices D and E.

1.3 Scope

This study addresses the Tactical Fuel and Energy Strategy for the future Modular Force. The primary issues affecting tactical fuel and energy options are those of availability, affordability, sustainability, and security from now into the 2015-2024 timeframe. This analysis reviews numerous other studies and provides an overview of ongoing efforts throughout the community of stakeholders.

1.4 Methodology

In formulating a viable Tactical Fuel and Energy Strategy for the future Modular Force, a meaningful, holistic, review of fuel and energy-related initiatives was undertaken. This strategy leveraged and harvested relevant data from many different sources. Ongoing research includes thorough reviews of available energy-related scientific, technical, and performance data from both commercial and Government agencies. We examined previous studies, strategic publications and other DoD-approved energy reduction initiatives to determine their suitability for application at the tactical level. Our analysts conducted interviews with Subject Matter Experts (SME) from industry and the government to assist in identifying the most promising technologies which support the Army's tactical fuel and energy reduction efforts and that we reasonably expected to reach an acceptable level of maturity by 2024. Additionally, the Army leadership identified several goals and focus areas that were used to guide and aid in the development of the Tactical Fuel and Energy Strategy for the future Modular Force (see Figure 1-1). In order to accomplish our objectives, we employed both quantitative and qualitative analysis. To aid in identifying capability gaps, we conducted a high level DOTMLPF analysis and developed metrics to aid in tracking progress on approved near-, mid-, and long-term pursuits.

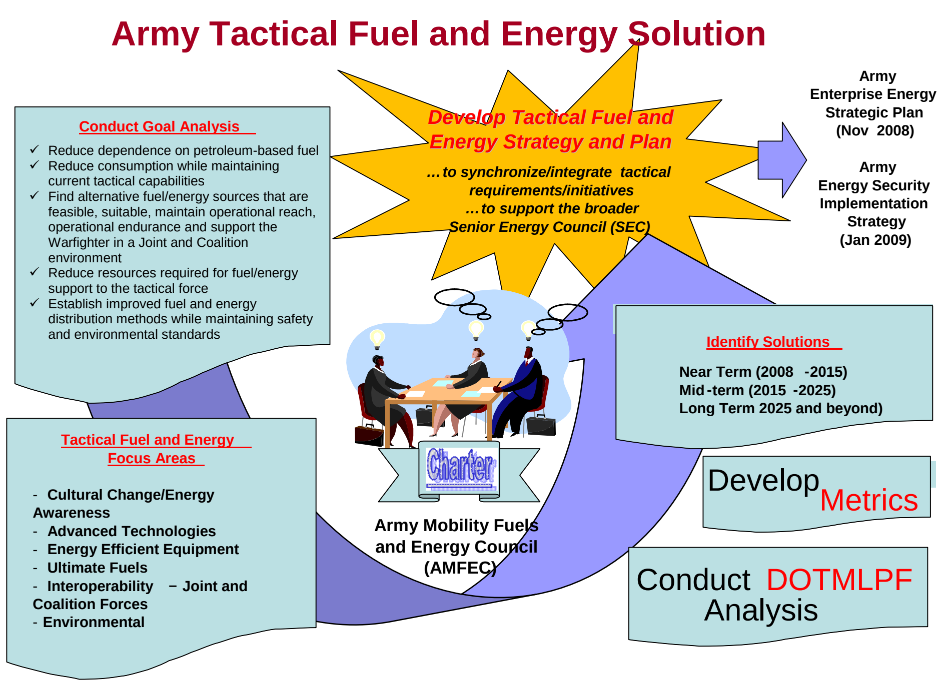


Figure 1-1. Army Tactical Fuel and Energy Solution.

Chapter 2: Need for Change

In May 2006, the Undersecretary of Defense for Acquisition, Technology, and Logistics (USD (AT&L)), directed the Defense Science Board (DSB) to create a Task Force to examine the DoD Energy Strategy[2]. Based on its study and deliberations, the Task Force concluded that tactical mobility operations suffer from the unnecessarily high and growing battle space fuel demand that 1) compromises operational capability and mission success; 2) requires an excessive support force structure at the expense of operational forces; and 3) increases life-cycle operations and support costs.

2.1 Energy Profile

The world energy demand is expected to grow 55% by year 2030. The demand for oil will increase by an estimated 36%; natural gas by 50%; coal use will double; while both nuclear and renewable sources will continue to grow[3]. Without a major technological breakthrough, the global energy mix will remain relatively consistent over the next 25 years, but future supply of petroleum-based fuels around the world is at risk because the "easy to produce" petroleum crude oil sources are in continual state of depletion and the "hard to produce" petroleum crude oil sources are not tapped either because they are prohibitively expensive to produce or the technology to produce them is not yet developed. The large majority of these easy sources are located in potentially unstable or hostile producer states.

Department of Energy (DoE) Assistant Secretary of Energy Efficiency and Renewable Energy, Alexander Karsner, said, "Our dependence on foreign oil is a serious problem that poses significant national security, environmental, and economic risks and only through American innovation and technological advancements will we solve this problem." By 2030, U.S. consumption is expected to outstrip U.S. production capability by approximately 2.5 times. Energy dependence is a strategic vulnerability for the U.S. and is driving the long-term pursuit of an alternative energy regimen and short-term actions to minimize risk of major energy disruptions (e.g., diversification, new supplier relationships, and stockpiles). In turn, these actions are affecting our national strategy, defense strategy and Army strategies.

The Government as a whole accounts for less than 2% of the total national consumption, but the DoD consumes over 96% of that. The Army consumes 16.8%, the Air Force 51.7%, the Navy 29.2%, the Marine Corps 1.4%, and other DoD agencies 0.7%[4] (see Figure 2-1).

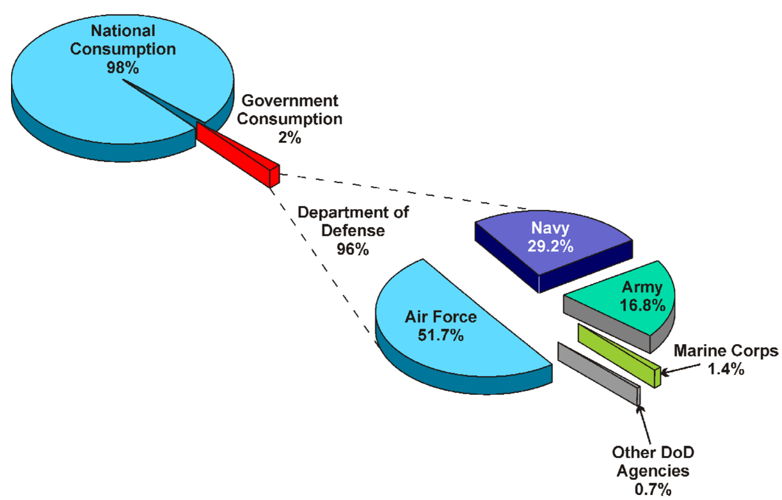


Figure 2-1. DoD Fuel Consumption.

[2] Report of the Defense Science Board Task Force on DoD Energy Strategy, July 2007.
[3] DoD Brief, Trends & Shocks – Energy, February 2008.
[4] DESC 2007 Fact Book: Available online.

2.2 Security Concerns

During the next 25 years, there will be a shift in the pattern of resource dependencies. In the developed world, political and environmental concerns, in concert with technological improvements, will lead us to seek a reduced reliance on petroleum-based fuel. Even though these same energy efficiencies will be available to developing countries, their increasing needs will lead to a greater demand for oil. India and China will see their energy demands rise to “first-world” levels. As these developing nations prosper, energy demands will grow as a result of increased heating, cooling, industrialization, and transportation needs. Issues of resource management will become significant in regions when population demands surpass local resources. Technology, alternative energy sources, and improved conservation methods will provide some relief, but potential conflicts over scarce resources could easily destabilize some regions.

Nations such as China are already investing billions of dollars into infrastructure to produce alternative fuels such as coal-based fuels. Our nation must be willing to invest at home and abroad in similar initiatives and to modernize our future combat systems with technological energy advancements, in order to fight and win this nation’s wars in the future.

2.3 Energy Strategic Plans

The goals developed for the Tactical Fuel and Energy Strategy are in concert with both the DoD Level Energy Security Strategic Plan and the Draft Army Energy Security Strategic Implementation Plan. Figure 2-2 provides a crosswalk of ongoing DoD/Army Energy Strategic Plans.

Crosswalk of Ongoing DoD/Army Energy Strategic Plans

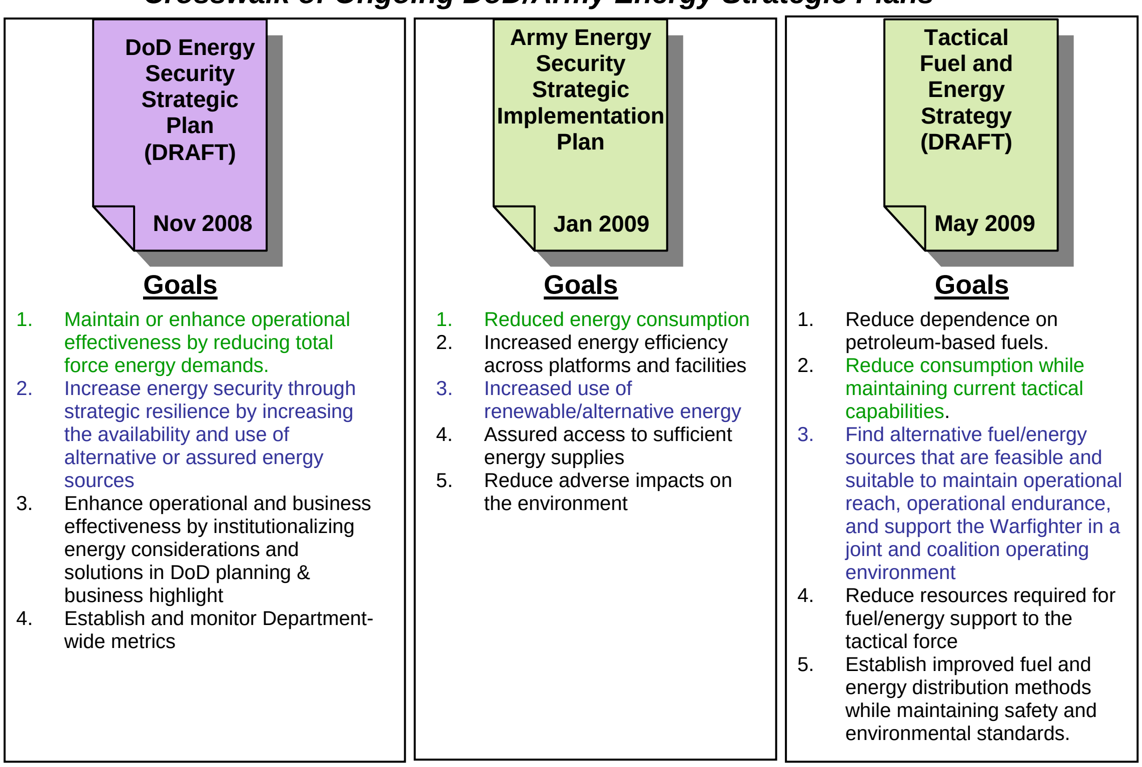


Figure 2-2. Crosswalk of Ongoing DoD/Army Energy Strategic Plans

Chapter 3: Future Tactical Fuel and Energy Goals Analysis

Working with industry, the Army plans to continue its focus on developing and demonstrating leading-edge energy initiatives that are ultimately employed for operational uses. Developing new technologies, management procedures, and energy practices are essential components of successful energy programs. Given that the Army's energy comes from diverse sources, is distributed across vast distances, and serves a wide variety of uses while meeting both cost and environmental constraints, it is critical that the Army become an energy innovator[5]. The Army must not only supply itself, it has Title X responsibilities for inland distribution of bulk petroleum for all land-based forces. Finding new ways to improve fuel efficiency in vehicles and using renewable energy resources will be a key enabler as the Army evolves into the future. Renewable energy resources are generated and replenished from natural resources such as the sun and wind. Below is a listing of six specific goals that must be addressed to meet the tactical demands for fuel and energy:

3.1 Goal - Reduce dependence on petroleum-based fuel

The U.S. currently uses 22 million barrels of oil per day, while it only produces approximately 8.5 million barrels per day. As a result, the U.S. and the Army are considerably dependent on foreign countries for the majority of its energy requirements. The world is likely to be constrained by limited oil supply, which will affect price and increase volatility, thereby decreasing the Army's energy security. This may not only affect the Army financially, but it can affect the operational tempo of the Army to ensure that chokepoints remain open in order to get oil to market. As this uncertainty prevails throughout the energy markets, the Army is emphasizing the fundamental importance of making energy security a priority to enable it to continue to meet its national defense missions.

To relieve the pressures of this nation's dependence on foreign oil, we must reduce consumption, use new energy sources as industry develops them, and where possible, make maximum use of renewable resources. The geopolitics of energy impact the energy security of the Army since supply concerns and potential energy interruptions could directly impact mission-critical operations. The sharp increase in petroleum prices resulting from tighter supply and international instability has raised critical concern about our dependence on petroleum imports. Under the umbrella of energy security, policy experts are making a case that as long as the U.S. continues to consume 22 million barrels of oil per day – 60% of which is imported – the nation will remain at the mercy of foreign oil suppliers, and unstable corrupt regimes[6]. They also note that terrorist groups such as al-Qaida view America's reliance on dwindling oil supplies as an Achilles' heel and a source of asymmetric power.

3.1.1 Discussion and Analysis of Goal

The Army operates in a complex energy environment. New federal laws and policies mandate energy reductions and additional legislation may be enacted to require reductions in carbon emissions. Recently, energy price volatility has increased significantly while the price of oil increased from an average of less than 40 dollars per barrel in 2004 to an average over 100 dollars per barrel in the latter half of 2008.

Diversifying energy sources is more than just about cost savings. Water and fuel account for 70% of the tonnage moved by convoys in Iraq and Afghanistan. These convoys are at risk from roadside bombs and snipers. Just moving fuel entails great danger to U.S. troops, and the cost of protecting those convoys keeps rising. The integration of hybrid electric vehicles into our fleet and maximizing the use of renewable energy could significantly reduce the number of convoys moving fuel. The design of these hybrid vehicles should be based on scientifically derived driving cycles that are representative of actual conditions Soldiers will face. The vehicles would also

[5] Draft Army Energy Security Implementation Strategy (AESIS), 6 January 2009.
[6] DoD Energy Security Strategic Plan (ESSP), Volume I: Strategic Plan, November 2008.

help to stabilize the conditions for conducting business in hostile areas around the world. This lowered burden translates into more efficient use of national resources — military and others.

Synthetic fuel is generally designed to behave much like conventional fuel - requiring little or no change in the equipment that uses it or the infrastructure for storing and distributing it - which makes it highly desirable to the DoD[7]. A 50-50 blend of synthetic and conventional fuel is currently being tested by TARDEC (Tank Automotive Research and Development Center) and is targeted for completion by 2011. However, this is a prime example of a solution to one goal not necessarily supporting other goals. This blend may reduce our dependence on petroleum-based fuels, but increase (slightly) the distribution assets required to deliver it. It is likely that this blend will have a lower energy density than straight JP8, which will require more fuel to accomplish the same mission profile. These conflicting results have to be addressed in a cost-benefit analysis in the implementation plan.

There are many other possible methods to achieve this goal besides the use of hybrid vehicles and synthetic fuel. Reducing the requirement is the quickest and most over-arching method, and that can be done through procuring more fuel-efficient equipment and changing operational behaviors, among others.

3.1.2 Status of Technology Enablers

Synthetic fuels are one of the most promising alternatives for Army in the mid and long term. However, synthetic fuels must be certified for use in tactical vehicles. Given the vast coal reserves in the U.S., coal becomes one of our other promising alternative fuels that shift our dependence away from foreign markets. The drawback becomes the huge investment required to modernize our industrial base to produce these coal-based products.

3.1.3 Conclusions

This goal can only be met through the synergies achieved through successful implementation of other ongoing energy and fuel reduction initiatives. Alternative fuel and renewable energy solutions should be developed to supplement fossil fuel requirements to the degree possible. While these can lessen the amount of petroleum-based fuels required, they will not be able to replace petroleum-based fuels in the near and mid terms. The degree to which these can be integrated into tactical operations is dependent on the spectrum of conflict.

3.2 Goal - Reduce consumption while maintaining current tactical capabilities

In his speech on oil and alternative fuels[8], President Obama indicated that the country faced many challenges, and he discussed some specific goals in moving toward energy independence. He specifically mentioned energy efficiencies and alternative or blended fuels. He stated, "If we hope to strengthen our security and create hundreds of thousands of new jobs, we can offer no less of a commitment to energy independence. Across the services, commanders and unit leaders are being asked to reduce fuel costs where they can. Any reduction in the consumption of petroleum-based fuel will lead to a corresponding decrease in our dependence on foreign oil; the reductions must be achieved without compromising operational capabilities. This is a major goal for a military fighting two wars and dealing with the uncertainty of future fuel prices."

3.2.1 Discussion and Analysis of Goal

The nature of the threat facing the U.S. has changed, requiring us not only to maintain forward forces, but also to be prepared for quick surge deployments worldwide[9]. These challenges require a more agile force, while increased mobility and responsiveness require greater fuel

[7] NREL, "Gas-to-Liquid Fuels, "Nonpetroleum Based Fuels, http://www.nrel.gov/vehiclesandfuels/npbf/gas_liquid.html, October 2006.
[8] President Obama's address to Congress, 25 February 2009
[9] U.S. Military Looks to Cut Fuel Costs, http://www.military.com, 20 October 2008.

consumption, and much of that fuel comes from foreign sources. Successfully reducing fuel consumption requires an understanding of the DoD energy consumption profile (how and where is energy being consumed), which is difficult to ascertain from the data available. In many cases, detailed energy supply data is available (what is delivered to the theater or the battlefield), but not detailed consumption data for actual military operations (how the fuel is actually used, e.g., tactical vehicles, logistics, and generators).

While capabilities cannot be compromised, there are many initiatives that can be implemented to reduce fuel/energy consumption without reducing operational reach and endurance. Some probable approaches for the near, mid, and far term strategies include:

- Reduce the operational fuel/energy consumption of existing platforms through selective technical retrofit or add new platforms applying technological enhancements;
- Make platforms lighter, without increasing their vulnerability;
- Increase the efficiency of propulsion/engine systems;
- Exercise more conscious maintenance considerations (i.e., tire pressure, reducing speed, using the proper oil in the engine, and use of clean air filters)[10];
- Design future systems with more effective fuel/energy efficiencies throughout the drive train;
- Use more lightweight materials in the manufacturing process to extend operational reach without reducing the capability of the platform;
- Supplement current battery systems with fuel cell technologies which have the potential to reduce consumption and prolong the life of the battery;
- Ensure items that are not needed for the current mission are not carried in the vehicle, thus reducing the overall weight and increasing mileage.

Many of these initiatives cost little to implement and can create immediate reductions. The simple act of removing an extra 100 pounds from the cargo load can increase gas mileage by as much as 2%[11]. Correcting minor maintenance issues like dirty air filters or low tire pressure can decrease consumption by as much as 4-5%, and equipment modifications, such as the Fuel Improvement Device and some Nano technologies have shown some potential for additional decreases.

3.2.2 Status of Technology Enablers

Mature technologies are currently available to support better fuel efficient vehicles. The vehicle industry is investing in turbochargers to improve efficiency by 10-15%, and is retooling to adopt plug-in hybrid, electric, and natural gas vehicles. Breakthroughs are desirable and needed, but the base technology is already available. Hybrids can provide reductions of 20% or more in light duty vehicles[12]. The reductions for Army tactical vehicles are dependent on the engines being designed for the Army's mission profiles and require more study for definitive results. Various alternative fuel options are being developed but have not reached the level of maturity needed to sustain the tactical force in the near term. The use of lightweight metals and/or composites to make systems lighter while maintaining current capabilities associated with the system is technologically possible and feasible now.

3.2.3 Conclusions

This goal can be achieved by aggressively pursuing various energy and fuel-saving initiatives, including developing fuel-efficient engines, developing energy awareness programs, developing

[10] Energy and Environmental Analysis, Inc. Owner Related Fuel Economy Improvements, Arlington, VA, 2001.
[11] www.fueleconomy.gov
[12] Ibid.

fleet maintenance programs, developing weight reductions programs for tactical vehicles, and pursuing alternative energy production/sources. The key issue for the Army/DoD is that the military typically does not value efficiency (fuel reduction criteria) at the same level of importance as commercial entities when making vehicle procurement or investment decisions. Much of that is understandable, given the Army's mission and use of these platforms, but there may be room for improvement. Reform of the business process needs to occur to add energy productivity as an evaluation criterion.

There are many different ways to achieve greater efficiency in fuel and energy consumption without reducing a platform's capability. These are solutions which can be implemented in the near-term and at little or no cost for most tactical equipment. Redesigning major components (i.e., engines, transmissions, etc.) take far longer, but could be in the mid-term range, provided funding was available. Total platform redesign goes into the far term, and can take as long as 20-25 years to accomplish. While it takes a great deal more time and money for equipment replacement, the benefits gained from the process can take advantage of the very latest technology advancements which would otherwise not be available through any other means.

3.3 Goal - Find alternative fuel/energy sources that are feasible and suitable to maintain operational reach, operational endurance, and support the Warfighter in a joint and coalition operating environment

The rapidly increasing price of fuel combined with the increased pressure for the Army to be more environmentally friendly has driven the development of alternative fuels options that until a few years ago were not considered to be viable. While it is uncertain which technologies will enter the marketplace, it is a safe assumption that a portion of the tactical fuels of the future will be derived from non-petroleum sources.

The term "operational reach" in this document is used to describe the distance and duration across which a platform can successfully employ its military capabilities[13]. The term "operational endurance" in this document is used to describe the time a platform can continue operating without refueling. For tactical platforms, there can be no compromise when looking for fuel savings if they degrade current capabilities. While we need to be more conscious of fuel/energy conservation, we must be able to maintain or exceed current tactical capabilities. However, that does not necessarily mean we cannot reduce consumption.

3.3.1 Discussion and Analysis of Goal

These alternative fuels include those meeting the JP-8 specification and shown to be completely suitable for use, but yet derived or partially derived (blends) from non-petroleum sources such as biomass, coal, natural gas, tar sands, shale oil, algae, and other plant oils or animal fats/tallows/greases. They are highly desired as alternative fuels for the Army as they will allow the Army to limit the number of fuels on the battlefield and align with the approach taken by the predominate DoD fuel user, the Air Force. The push to develop alternative fuels, although driven by energy security concerns, has been aided by concerns over the environment. Many alternative fuels lead to reductions in emissions of toxic chemicals, ozone-forming compounds, and other pollutants, as well as greenhouse gases.

Synthetic fuels are one of the most promising alternatives for the DoD in the mid and long term. One example is Fischer-Tropsch (FT) fuels (a name based on the chemists who developed the process). FT technology can convert various resources such as coal, natural gas, biomass, and also petroleum coke (a low-value refinery by-product) into a high-value, clean-burning fuel. The resultant fuel is colorless and odorless. In addition, it is interchangeable with conventional diesel fuels for many applications and can be blended with diesel with little to no modification. FT fuels offer important emissions benefits compared with diesel, reducing nitrogen oxide, carbon

[13] JP 3-0, Joint Operations and JP 1-02, Joint Dictionary.

monoxide, and particulate matter. The primary challenge with FT fuels is that they contain essentially no sulfur and no aromatics. Petroleum diesel and jet fuels, on the other hand, do typically contain sulfur and aromatics. This difference requires their suitability for use to be completely established to ensure the performance and durability of equipment in which they are used is not adversely impacted to the extent that it outweighs the benefits.

Currently, there are numerous cars and trucks available for purchase off the dealer showroom floor that use something besides gasoline or diesel fuel for a power source. If any of these vehicles could be adapted for a military mission and pass the necessary certification tests then they could be used by the Army. Currently, there are no commercially-available hydrogen-powered vehicles in widespread markets. However, vehicles that use other fuels, listed below, are available in certain parts of the U.S.:

- Liquefied Petroleum Gas (LPG), commonly known as propane
- Compressed Natural Gas (CNG)
- Liquefied Natural Gas (LNG)
- Methanol (M85)
- Ethanol (E85)
- Biodiesel (B20)
- Electricity

3.3.2 Status of Technology Enablers

Synthetic fuels are one of the most promising alternatives for the DoD in the near term. FT technology converts coal, natural gas, and low-value refinery products into a high-value, clean-burning fuel. Biomass waste-to-energy technologies (thermal/ combustion) are very mature. A number of companies are researching and developing other biomass feedstocks, including algae-to-biocrude. These plants are typically site-specifically designed for raw material input and must consider logistics of raw material supply, operating energy requirements, and utilization of various types and quality of energy/fuel output.

Mature technologies already exist to aid in meeting the Army's operational reach and endurance goal. This goal can be met by implementing other associated fuel and energy reduction initiatives previously discussed.

3.3.3 Conclusions

The Army cannot drive the developmental effort, but must position itself to be able to take full advantage of these fuels as they become available. To do this in a cost-effective manner, the Army must develop a process and implement a policy for the qualification and approval of alternative fuels in tactical systems. The Army may be required to provide some funding for R&D biomass-to-fuels and hybrid system efforts as a means to prove new, more effective technologies, and provide incentives to industry. Industry and other parts of the government, like the Department of Energy, must lead the way and provide the bulk of the funding, but the Army should follow their lead. Resultant benefits include cost effectiveness (lower cost with hybrid systems), physical security, energy independence, waste management, and sustainability.

There are many different ways to achieve greater efficiency in fuel and energy consumption without reducing a platform's capability. These are things that can be done near-term and for most tactical equipment cost little or nothing to implement. Redesigning major components (i.e., engines, transmissions, etc.) take far longer, but could be in the mid-term range, provided funding was available. Total platform redesign goes into the far term, and can take as long as 20-25 years to accomplish. While it takes a great deal more time and money for equipment replacement, the benefits gained from the process can take advantage of the very latest technology advancements which would otherwise not be available through any other means. The ability of our Army to fight

and win its future wars is inextricably linked to our ability to adapt to the changing global energy environment and to leverage advancing energy technologies into our Warfighting platforms.

3.4 Goal - Reduce resources required for fuel/energy support to the tactical force

Strategic reach provides the capability to operate against complex, adaptive threats operating anywhere. The distance across which the U.S. can project decisive military power is its strategic reach. It is this capability, coupled with an ever-demanding electronic technology progression that creates the need for the support forces required to maintain these technologies. From the vast but simplistic capabilities in WWII to the comparatively complex capability of today, we have seen the ever-increasing need for fuel/energy to support this force and its ever-expanding capabilities.

3.4.1 Discussion and Analysis of Goal

Along with this capability comes a large support bill which continues to grow as our capabilities grow. While there has been a continuous influx of research and development dollars for weapons systems, there has been very little done for the support for these systems. Obviously, we cannot give up these capabilities which have evolved over the last 200 plus years, but we can no longer afford the logistical burden to support them. In order to reduce support requirements, we must reduce consumption while maintaining current and future capabilities.

The Army's goal for fuel on the battlefield remains as one single kerosene based fuel, JP8 or equivalent. Currently, in Operation Iraqi Freedom (OIF)/ Operation Enduring Freedom (OEF) we are using at least seven different fuels[14]:

- TS1 (Russian equivalent to Jet A)
- JP8;
- Diesel
- Mogas
- AVGAS
- DF/JP (DF1) (winterized diesel 50/50)
- Ultra low sulfur diesel used only by the Air Force

This adds additional support requirements with additional resources because of the different types of fuel (i.e., storage requirements and fuel trucks, since one cannot mix fuels). How did the Army come to require these different types of fuel on the battlefield when their requirement is still one single fuel? There are many different reasons which include contractual oversights, a mixture of old and new equipment, the expeditious development of new equipment, coalition force requirements, and local fuel/energy availability considerations prior to the commitment of forces.

Table 3-4. Fuels Used In Operation Iraqi Freedom/Operation Enduring Freedom (FY08)

[14] Information furnished by the Army Petroleum Center, teleconference call from CASCOM and APC, 22 April 2009.

FUEL TYPE	GALLONS	% OF TOTAL
JP-8	465,533,483	74
Mogas	25,142,473	4
TS1 (Russian equivalent to Jet A	16,761,266	3
Diesel (DF2)	115,092,981	18
DF/JP (DF1 – winterized diesel 50/50)	7,332,318	1
Avgas	612,738	0.1
Total	630,475,259	100

Developing new equipment and/or modifications to current equipment to achieve fuel/energy economies takes time and a great deal of investment. Alternative fuels and renewable fuels have the potential to reduce the quantity of fuel required to support today's operational battlefield. Additionally, reducing the weight of weapon systems, developing more fuel/energy efficient engines, fuel cell technologies, increasing solar energy use, and developing waste to fuel capabilities where applicable are all possibilities for reducing overall fuel consumption.

Fuel/energy produced at the site of consumption means that it does not have to be transported to that site or the transportation requirements and frequencies are reduced. Any reduction in consumption through gained efficiencies means fewer convoys, and that means a possible overall manpower and equipment savings.

3.4.2 Status of Technology Enablers

Mature technologies currently exist to support this goal in the near to mid term. Moreover, energy and fuel saving initiatives that reduce overall consumption will also reduce distribution requirements. Initiatives such as the Modular Fuel System (MFS) facilitate greater forward positioning and distribution of fuel, thereby reducing the number of convoys required. Larger fuel transport tankers are an option that could result in fewer assets being required to support the force, but this solution must take into account the off-road requirements along the distribution route that may not be trafficable by the larger tankers. The use of solar power and intelligent power distribution in the base camps also provide technological solutions.

3.4.3 Conclusions

To accomplish this goal, the Army must invest in the necessary technologies needed to provide the support and reduce the resources needed for that support. Additionally, a cultural change is required – change in attitudes toward energy and how we go about accomplishing our day to day missions. The "Predominant Fuel on the Battlefield"[15] concept remains a viable option and one which the DoD should continue to strive to attain. The functions of fuel storage, transportation, and distribution can be tailored for maximum efficiency with a single battlefield fuel. Transportation assets will not have to undergo conversion (a timely process) to transport multiple fuels. The same transportation assets can deliver fuel to all types of aviation and ground units. The capability to provide emergency resupply will be increased. Overall readiness will be improved.

3.5 Goal - Establish improved fuel and energy distribution methods while maintaining safety and environmental standards

One of the biggest contributors to the fully burdened cost of fuel is the distribution of that fuel from the source to the end user. Fuel used on a mountaintop in Afghanistan can start as crude oil in Saudi Arabia, move by ocean tanker to Karachi, Pakistan where it is refined. After short pipeline movement, then get loaded on trucks for a cross-country journey to the Afghanistan border. Move into Afghanistan by truck to be delivered to Bagram, Air Base. Get loaded again for

[15] The current "Single Fuel on the Battlefield" policy is undergoing change to be the "Predominant Fuel on the Battlefield" and is referred to as such by direction of the study sponsors. Information furnished by Mr. Bill Carico, teleconference call from CASCOM and G-4, 5 May 2009.

movement to a forward operation base, where it is again unloaded. Finally, get loaded into a 500 gallon blivet for slingload to the site. Any decrease in the amount of fuel required will decrease every leg of this journey. Worldwide, the concern over energy security grows deeper. As global energy demand increases, prices continue to rise and both of these trends make this distribution more difficult. Solutions to the distribution issue, however, must meet increasingly restrictive environmental and safety standards. Many alternative fuels have lower emissions than the currently used fuels. However, some of the processes tend to create a substantial amount of carbon dioxide, which must be sequestered if any real environmental benefits are to be gained, yet another tradeoff among goals. The push to develop alternative fuels, although driven by energy security concerns, has been aided by concerns over the environment, because many alternative fuels lead to reductions in emissions of toxic chemicals, ozone forming compounds, other pollutants, and greenhouse gases.

3.5.1 Discussion and Analysis of Goal

It takes a great deal of reduction to actually decrease distribution requirements. Alternative fuels and renewable fuels have the potential to substantially reduce the quantity of fuel required to support today's operational battlefield. Fuel cells, solar energy, and waste to fuel capabilities, while not immediately available in the capacity we require today, could be the answer to tomorrow's energy needs, all of which will reduce the distribution requirements substantially.

For the near term though, we have today's distribution capability, which is cumbersome, difficult to deploy/operate, and manpower/equipment intensive. There are some modernization systems available, but funds are lacking. The Modular Fuel System (MFS) and the Rapidly Installed Fluid Transfer System (RIFTS), which provide advance distribution capabilities, are available in the near term. Both systems have reduced manpower and equipment requirements and can be deployed more quickly and efficiently. RIFTS can emplace and operate 20 or more miles of hose line per day. Solar power, coupled with fuel cells, could reasonably be expected to replace selected generators in most areas. Flexible solar panels exist today which could be placed over a tent to provide operational electrical requirements (i.e., air conditioning, heating, lights, and computer usage for tents with an office mission). Both of these applications are being tested now and could very well be available in the mid term and beyond.

3.5.2 Status of Technology Enablers

Mature technologies already exist to aid in meeting this goal. Essentially, solar power is a mature technology, but there are a few short term restraints on material supply for manufacturing given the upswing in solar projects. In terms of solar technology insertion, solar energy systems need to be integrated with an electric system to allow for interoperability to provide maximum economic benefits. Fuel cells and waste to fuel capabilities, while not immediately available in the capacity we require today, might support mid to long term goals.

3.5.3 Conclusions

Alternative fuels in and of themselves will not reduce fuel distribution requirements. However, alternative sources of energy could reduce distribution requirements. For example: 1) Solar power for lights, air conditioning, heating, etc.; and 2) Waste to energy capability. Fuel/energy produced at the site of consumption means not having to move fuel to the site to produce power for as many platforms. Any reduction in fuel requirements means fewer convoys and a possible overall manpower and equipment savings. MFS and RIFTS can be matured into production in the near-term and could be deployed quickly and efficiently.

Chapter 4: Tactical Consumption Assessment

The new way of fighting wars/terrorism in today's environment means a higher level of mobility, to include logistics, and without changes that will mean more fuel and energy as the Army evolves over the next 20 years. Tactical equipment accounts for the majority of the fuel consumed by the Army. The Army's tactical equipment is routinely involved in offensive operations, defensive operations, mission staging, and stabilization operations that include cross-country and travel over improved roads. Predictability on when, where, and what future operations the Army may be involved in is highly speculative and imprecise at best.

The following paragraphs provide an overview of fuel consumption by tactical platforms. The data in sections 4.1, 4.2 and 4.3 was pulled from the OSMIS database fuel and OPTEMPO sections. While it does not cover all tactical platforms and equipment it does provide a representative sampling of the major items of equipment. The data shows which systems are using the most fuel and provide direction for focusing our efforts on where the Army can make the most impact with fuel efficiency efforts as the Army continues to move forward. The data in section 4.4 regarding generator use is based on TRADOC planning factors as generator fuel consumption is not tracked by any automated data collection system. For the purposes of this study, we will look at the consumption for four major categories of platforms and the top consumers in each, which make up the majority of the equipment in the tactical equipment Army. Over a seven year period (2000-2006)[16] the Army paid over $1.2 billion for fuel to power tactical platforms, averaging more than $175 million per year[17].

4.1 Aviation

This category consists of over 4,600 airframes and uses an average of 97 million gallons of fuel per year. In 2006 the Army spent $286 million for fuel, and aviation accounted for 55% of that cost. The top three systems (Blackhawk, Chinook, and Apache) account for 94% of the fuel costs in the Aviation category and 52% within the Army. The average number of airframes in the Army is 4631 with a little over 25% (average 1158) deployed in support of CONOPS since 2003.

4.2 Combat Vehicles

This category includes most tracked vehicles (except medical) and the Fox and Stryker wheeled vehicles. These vehicles consist of over 36,000 platforms and use an average of 21 million gallons of fuel per year. The top five combat systems (Abrams, Stryker, Bradley, APC and MLRS) represent 94% of the fuel costs in this category and 11% of the Army's tactical fuel costs. The M1 Tank by itself accounted for 61% for this category and 7% of the Army's cost for tactical platforms. Roughly 22% of the combat vehicles are deployed in support OIF and OEF. Of the 36,000+ systems in the Army, approximately 7800 are deployed on average.

4.3 Tactical Vehicles

This category consists of over 319,000 platforms and uses an average of 62 million gallons per year. The top five consumers in each platform (HMMWV, HEMTT, M939 series, M915 and PLS) account for 73% of consumption for this category and 24% within the Army. These platforms make up the majority of the tactical equipment in the Army representing 89% of the density of total tactical platforms. Approximately 29% (93,000) of the Army's tactical vehicles are deployed on average.

[16] Operating and Support Management Information System (OSMIS) Database FY 2000-2006
[17] Army G4 Brief, Platform Metrics, 26 October 2007.

4.4 Generators

The Army uses over 102,000 generators for its operations, ranging in capability from 2 kW to 840 kW. TRADOC planning factors indicate that the total generator population would consume 357 million gallons of fuel per year in a deployed scenario. Based upon the deployment percentage for aircraft and vehicles we estimate that approximate 25% of the total generator fleet would be deployed at this time. Using this deployment percentage total generator consumption is estimated at 89 million gallons per year. However, even when averaging peacetime with wartime consumption rates, generator sets, as a rough approximation, remain one of the largest consumers of fuel in the Army.

Chapter 5: Innovative Concepts and Energy Options

In the future, alternative energy sources will become more prevalent. As the Army moves forward it must consider all viable options for inclusion in current and future platforms. Hydrogen, various forms of atomic energy, and hybrid systems could potentially lessen reliance on petroleum-based fuels. If this occurs, the Army's logistical footprint could potentially be reduced due to decreased demand for petroleum-based fuels and the number of military convoys required to transport these commodities. Some of these options may increase the number of convoys required. This is another example where a trade-off analysis must be completed in order to fully evaluate the impact across multiple goals. In turn, combat forces would be able to operate for longer periods of time without resupply. Additionally, sensors and systems would have longer ranges and greater persistence, powered by derivatives of alternate energy sources that replace or enhance current battery technology. Greater lethality reduces the number of platforms required to engage targets, which in turn reduces energy demand. Systems that can kill will have greater lethality in every environment: Land, sea, air, and space. With less than one-half of one percent of the national use, the Army will not drive emerging technologies.

5.1 Development of Innovative New Concepts

Listed below are numerous methods of accomplishing fuel/energy savings readily available to the U.S. Army. Some are currently being developed, a few are now in testing/evaluation, and others merely require implementation.

5.1.1 Fuel Efficient Engines

Military diesel (JP8) engines used in combat and tactical applications have their own specific engine control requirements that differ from those of commercial heavy-duty vehicles. The implementation of advanced engine control methods in diesel-powered military vehicles can result in an increase in their performance, a reduction in their fuel consumption, a reduction in their observable exhaust emissions, and an improvement in their stealth capabilities. Neural network-based engine control has the potential to allow for the simultaneous, optimized control of several engine parameters such as fueling quantity, injection timing, injection pressure, and turbocharger boost pressure.

Future engines will be considerably more complicated in their control, incorporating such additional technologies as variable geometry turbo charging, variable valve timing, and multiple injection strategies. The advanced engine control techniques developed here will facilitate the optimal control of these more sophisticated engines in future military applications. There is a growing need in the military for high efficiency, high performance power trains for tactical vehicles. By electrifying conventional belt and gear driven "under-the-hood" auxiliaries that normally draw power from an internal combustion engine such as water and oil pumps, heating and air conditioning, cooling fans, and power assisted steering and brakes, the load on the engine is lessened. This results in fuel efficiency improvement and reduced emissions[18]. In order to power these auxiliaries, the conventional alternator must be replaced with a higher power, efficient generator, which can also provide export power to run other on or off-board equipment.

5.1.2 Fleet Management

Managing fuel requirements for the tactical fleet of vehicles is challenging, at best. First, personnel tasked with managing fuel must address security of supply, ensuring fuel is available when and where it is needed on the battlefield. Secondly, these personnel are challenged to maximize throughput, which is not an easy job within a supply chain that is in constant fluctuation, particularly in a tactical situation. By centralizing operations, creating strategic supply

18 www.greencar.com/articles/vehicle-electrification-more-fuel-economy.php

relationships, and automating key processes in fuel management for the tactical fleet, managers not only save in fuel consumption and costs, but can ensure responsive and efficient logistical support to the Army in the field.

5.1.3 Energy Awareness

Energy Awareness Training includes:

- Publicizing the goals, strategies, successes, and lessons learned of the Army Energy Program.

- Implementing driver feedback devices[19] producing and increasing Army military knowledge of energy efficiency and conservation.

- Developing products that will change the behavior of Army personnel, resulting in decreased energy use developing and transferring technical and program management information.

- Assisting the tactical commander in meeting energy reduction goals through awareness education. Most institutions are slow or resistant to change. The objectives of Energy Awareness Training will help to institutionalize this change.

5.1.4 Simulators

Simulation-based training plans provide organizations with an unprecedented ability to provide effective training for operators on a wide variety of equipment and other machines. Organizations have a cost-effective and highly-realistic solution for initial training and skill refinement to complement seat time in an actual piece of equipment or machine. Simulations in training can be both cost-effective and less time-consuming than normal classroom or hands-on instruction. Simulators enable organizations to make more effective use of their capital assets and maximize the availability and capability of their equipment and operators. According to fleet professionals, using a more efficient vehicle will not be enough for significant savings unless the people behind the wheel change the way they drive[20]. Simulators can be used to achieve simple changes in driver habits, which can result in significant fuel economy savings. There are six basic techniques suggested by the industry that could result in savings when put into practice. Examples of eco-driving techniques are: minimize speed, accelerate slowly, up shift at low RPMs, maximize time in top gear, keep a steady foot on the accelerator, and avoid overuse of engine braking. While these suggestions may conflict with combat-driving techniques to some extent, they can be a part of an overall strategy to decrease consumption.

5.1.5 Fleet Maintenance

Fleet maintenance is very important. It ensures that all vehicles within a fleet are performing as they should. If any maintenance problem arises, organizations can arrange for those problems to be addressed before they become larger issues that might negatively impact the mission. Equally important is the need to perform regular maintenance on the vehicles within a fleet to improve fuel efficiency. There are a number of factors that can affect fuel efficiency. The three main factors are clean air filters, proper tire inflation and use of the proper motor oil. Examples of factors that can potentially impact a fleet's fuel efficiency are: Air filters - when an air filter is clogged, it negatively impacts a vehicle's fuel efficiency by up to 10%. The air filter also prevents impurities from damaging the inside of the vehicle's engine, so there are benefits to making sure a clogged air filter is replaced; Tires - Gas mileage can be improved by around 3.3% by keeping tires inflated to the proper pressure. For every psi drop in pressure, gas mileage is lowered by 0.4%[21]. Additionally, gas mileage can be improved by 1-2% by using the manufacturer's recommended

[19] http://www.businessweek.com Fords Green Plan to Drive Sales, 8 December 2008.
[20] ARI – Automotive Resources White Paper, Fuel Cost Reduction Strategies, Controlling the Controllable, 2008
[21] http://www.fueleconomy.gov

grade of motor oil[22]. Also, motor oils that are marked "energy conserving" are especially helpful as they contain friction reducing additives.

5.1.6 Platform/Equipment Weight Reduction

The increased fuel efficiency that can result from the use of lightweight materials has many additional benefits. Reduced fuel consumption would result in a reduced logistics footprint because less equipment and fewer personnel would be required to support a unit in the field. The true cost of fuel, including delivery, for the Army in normal times is approximately $13 per gallon. The military vehicle multiplier for weight savings is therefore several times that of civilian vehicles. These requirements mandate that Army trucks consume less fuel, undergo significant weight reduction, have a reduced logistics footprint, and need less maintenance while maintaining or increasing payload capacity and other performance criteria. It is estimated that every extra 100 pounds of weight a vehicle carries reduces its fuel efficiency by 2%[23]. The reduction is based on the percentage of extra weight relative to the vehicle's weight and affects smaller vehicles more than larger ones. Weight reduction must occur without compromising the survivability characteristics required for the particular platform prescribed.

5.1.7 Alternative Energy Production

The rapidly increasing price of fuel, combined with the increased pressure for the DoD to be more environmentally friendly, has driven the development of alternative fuels that were not considered viable a few years ago. While it is uncertain which technologies will enter the marketplace, it is a safe assumption that a portion of the tactical fuels of the future will be derived from non-petroleum sources. There is a process in place to examine and integrate non-petroleum derived fuels[24]. The DoD must position itself to be able to take full advantage of these fuels as they become available. To do this in a cost-effective manner, the DoD must develop cost- effective test and certification protocols across all the services that can be used to approve alternative fuels for tactical systems.

The DoD is currently testing small systems that can convert waste from an Army base camp into fuel. While the quantities are not large, if successful, the system could address two problems: reducing the challenge of properly disposing of waste from deployed locations and reducing the amount of fuel needed to be moved by convoy to forward locations. Though the DoD is making progress, the biggest drawback is the large requirement of raw material needed to produce the fuel for the unit in-theater,

The DoD is also testing a hybrid renewable energy system for forward locations. It consists of a photovoltaic array, a wind generator, and a power management system to integrate the sources with the load. The type of testing to date has been exploratory R&D, not without its issues. The Air Force has begun a structured program to test synthetic fuels made from the FT process and plans to certify all aircraft to use the fuel in a 50/50 blend. The farther forward that these savings occur, the greater the overall impact is on the fuel distribution requirements. Fuel at the Forward Operating Bases (FOBs) in Afghanistan, for instance, is shipped from outside the country to major distribution hubs, then usually shipped again to smaller hubs, before finally being moved a third time to the using unit. Every gallon saved eliminates three shipments.

5.1.8 Alternative Fuels/Energy

Currently, the ability to operate tactical vehicles in forward-deployed locations over extended periods requires the ability to establish long, logistically cumbersome supply lines for JP8 and other fuels, resulting in additional high costs and risks to personnel who drive and escort fuel convoys. In addition, the rising costs for petroleum make the development of alternative fuel sources for military vehicles an increasingly pressing need. One promising solution to these

[22] ibid
[23] http://www.fuel economy.gov
[24] MIL-DTL-83133F, Turbine Fuel, Aviation, Kerosene Type, (JP-8 (NATO F-34), NATO F-35, and JP-8 +100 (NATO F-37) Detail Specification, 11 April 08.

urgent military needs is found within the broad purview of biofuels. To date, biofuels research has focused primarily on large-scale ethanol production from corn grain (starch) and sugar cane (sucrose) that, while reducing the environmental impact and the dependence on foreign fuel sources, still suffer from dependence on long supply lines, dependence on food crops, low gallon per acre yield, and high energy requirements. However, ongoing research into non-food feedstocks for synthetic fuel production (e.g., bagasse, corn stover, wood, switch grass, and other grasses), other photosynthetic biomass sources such as algae, combined with rapid progress in genetics and biotechnology, and advances in small-scale processing technology could make tactical in-theater production of biofuels possible. Specifically, high-yield ethanol or oil-producing systems, combined with efficient, small–scale, solar-powered biofuels harvesting and production, is desired. The proposed system must be capable of producing tactically relevant quantities of biofuels at long-term, forward "off-grid" operating sites. Although possible, fielding of such a system will require a thorough trade-off analysis to deconflict the many issues surrounding such an endeavor, e.g., feedstock availability, site operation, environmental, etc.

5.1.9 Intelligent Power Distribution

An intelligent power distribution system precisely connects power consuming and power producing devices. Such a system links intelligent devices that can externally communicate to an automated power manager. This is vital to energy usage, particularly in a tactical situation (i.e., an Army base camp). Electricity networks are extensive and well established. They form a key part of the infrastructure that supports industrialized society. These networks are moving from a period of stability to a time of potentially major transition, driven by a need for old equipment to be replaced as a result of government policy commitments to cleaner and renewable sources of electricity generation, and changes within the power industry. The novel transmission and distribution systems of the future will challenge today's system designs. They will cope with variable voltages and frequencies and will offer more flexible, sustainable options. Intelligent power networks (smart grids) will need innovation in several key areas of information technology. Active control of flexible, large-scale electrical power systems is required. Protection and control systems will have to react to faults and unusual transient behavior and ensure recovery after such events. Real-time network simulation and performance analysis will be needed to provide decision support for system operators and the inputs to energy and distribution management systems. Advanced sensors and measurement will be used to achieve higher degrees of network automation and better system control, while pervasive communications will allow networks to be reconfigured by intelligent systems. This is a clear example of where the Army can take advantage of what the power industry is forced to develop given the changing energy environment. The complexity of the systems required for the commercial market are equivalent to the needs of the Army in the field, and it can leverage that development.

5.1.10 Single Fuel on the Battlefield

A single fuel on the battlefield is really as much about logistics as it is about fuel. For liquid or gaseous fuels, maintaining multiple pipeline, storage, and distribution networks (trucks/tankers) is impractical and contributes to the logistics burden for the military[25]. The functions of fuel storage, transportation, and distribution can be tailored for maximum efficiency with a single battlefield fuel. Transportation assets will not have to undergo conversion (a timely process) to transport multiple fuels. The same transportation assets can deliver fuel to all types of aviation and ground units. The capability to provide emergency resupply will be increased. Overall readiness will be improved as a result of this effort. A single battlefield fuel will guarantee the Army's interoperability with other U.S. military ground-based services.

[25] Information furnished by Dr. James Cross, RDECOM Power and Energy TPT, 8 May 2008

5.1.11 Fuel/Energy Accountability and Management

Managing energy supply and demand is critical to sustaining force and system readiness. It is imperative that the Army maximize its operational capability and effectiveness by mitigating risks to energy supply[26]. As of 7 January 2009, all new Army acquisition programs with end items that consume energy shall include the Fully Burdened Cost of Fuel (FBCF) needed to operate the system in their total ownership cost analysis. The price that DoD pays for fuel is generally thought of as its cost, but this is not its actual cost. The true cost of fuel includes not only purchasing the fuel, but also delivering it to operational forces. FBCF can also inform choices between non-materiel solutions across the DOTMLPF spectrum that affect operational fuel demand. A number of recent studies concluded that most of the DoD's energy cost is in its delivery. There is a newly-approved methodology for developing the FBCF. The FBCF will be estimated for the analysis and evaluation of alternatives. Program Managers will be required to ensure that the FBCF or an appropriate derivative is used in fuel and energy demand trade studies. The FBCF is the fuel commodity price plus the total life cycle cost of all people and assets required to move and protect fuel from the point-of-sale (usually the Defense Energy Support Center off-load point) to the end user[27]. The approved seven-step process for estimating the FBCF is as follows:

- Step 1 - Commodity cost of fuel.
- Step 2 - Primary fuel delivery asset operation and support cost.
- Step 3 - Depreciation cost of primary fuel delivery assets (e.g., apportioned replacement costs).
- Step 4 - Direct fuel infrastructure operation and support and recapitalization cost.
- Step 5 - Indirect fuel infrastructure operation and support cost (including force protection of logistics forces).
- Step 6 - Environmental cost.
- Step 7 - Other service and platform delivery specific costs.

The Defense Logistics Agency's Business Systems Modernization-Energy (BSM-Energy) is an Automated Information System (AIS) designed to support the Defense Energy Support Center (DESC) and the Military Services in performing their responsibilities in fuel management and distribution. BSM-Energy is multi-functional AIS that provide point-of-sale data collection, inventory control, finance and accounting, procurement, and facilities management information. BSM-Energy will support the business functions of acquisition and contract management, supply management, facilities management, financial management, and decision support. The BSM-Energy's Fuels Manager (FM) software is used to communicate to the point-of-sale Automated Tank Gauging systems. It can be configured to provide a graphical representation of tank levels and alarms. The BSM-Energy Fuels Control Center (FCC) software provides the accounting management utilities required for billing. FCC is configured to download point of sale transactions from AFSS systems. The objectives of the BSM-Energy program are as follows:

a. Increase fuel accountability by supporting fuel transactions at all Defense Fuel Support Points (DFSP) and retail point-of-sale data collection sites.

b. Decrease data processing time through the use of modern automation techniques which are compatible with the Electronic Data Interchange (EDI) standards. Integrate new fuel technology systems (automatic tank gauges, automatic leak detection, and reporting systems) into BSM-Energy.

c. Provide a mechanism for specialized customer support through customized terminal interfaces which allow user-generated database queries on accounts.

d. Use telecommunications assets that promote real-time or near real-time data processing.

[26] Memo, SAAL-PA, Subject: Energy Productivity in U.S. Army Weapon Systems, 7 January 2009.
[27] Memo, SAAL-PA, Subject: Guidance for Energy Productivity in U.S. Army Weapon Systems, 7 January 2009.

e. Integrate Commercial Off-the-Shelf (COTS) financial module in concert with the Defense Finance and Accounting Service (DFAS), the Defense Logistics Agency (DLA), and Military Services (MILSVCS).

f. Develop an energy information management system migration process for technical modernization of platforms and implementation of new/revised/efficient business practices.

5.1.12 Fuel Efficiency

The development of and commitment to hybrid electric architecture for Tactical Wheeled Vehicles (TWV) can potentially reduce overall fuel consumption without hindering our current operational capability. Potential fuel savings for hybrid-electric (HE) vehicles would depend on designing the vehicle to derived driving cycles that are representative of actual conditions. Important features are vehicle architecture, leveraging other technology investments, energy conversion options, fuel quality issues, emission standards and energy storage. Not all hybrids are equally fuel-efficient. There is a large difference between a “mild hybrid”, in which the electric motor may operate only at starts and stops, and a “full hybrid”, in which the electric motor does most of the work, with only occasional support from a small gasoline engine. The diesel hybrid could potentially improve Army fuel consumption over conventional diesels, reduce emissions and provide Soldiers with reliable electrical power. These are crucial elements in helping to transform the Army into a lighter, more mobile military unit.

5.1.13 Fuel Cells

Fuel cells are an efficient, combustion-less, virtually pollution-free power converter. They operate much like a battery, using electrodes and an electrolyte to generate electricity. Unlike a battery, however, fuel cells never lose their charge[28]. As long as there is a constant fuel source, fuel cells will generate electricity. Today, fuel cells are being developed for applications such as providing on-site power (and waste heat in some cases) for military bases, banks, police stations, and office buildings, from natural gas. Fuel cells can also convert the energy in waste gases from water treatment plants to electricity. In the near future, fuel cells could be used in Auxiliary Power Units (APU) on heavy duty trucks and Recreational Vehicles (RV) or propelling automobiles and allowing homeowners to generate electricity in their basements or backyards.

Fuel cell technologies include several systems that are appropriate for different TEP output regimes given further development. Since well-designed fuel cell power sources can be more efficient than diesel-to-electric conversion, i.e., ~50% or somewhat greater compared to ~30 to 40% for diesel engines, fuel cells are an attractive means of supplying power, while reducing the need for fuel[29].

On a much larger scale, highly efficient megawatt-capacity fuel cell advanced power systems will use coal syngas to provide power with near zero emissions, significantly reducing the water footprint and capturing more than 90% of carbon dioxide. While the first generations of fuel cells continue to spur interest in fuel cell technologies, the focus of the DoE's fossil energy fuel cell program is to develop a much lower-cost fuel cell and develop fuel cell coal-based systems. The cost target is $400 per kilowatt or less, which is significantly lower (by about a factor of ten) than current fuel cell products[30]. It is expected that lower-cost fuel cells will successfully compete with alternative technologies. Ultimately, coal-based systems will be scaled up and integrated into large (greater than 100 megawatt) fuel cell power blocks. The primary reason that fuel cells are not being installed everywhere is the cost of premium fuels and the cost

[28] http://www.fossil.energy.gov/programs/powersystems/fuelcells.
[29] T. E. Raney, BAE Systems, Inc., Energy Conversion Efficiencies - Basic Calculations & Technologies Briefing, 22 October 2008, pg. 3.
[30] ibid.

of fuel cell systems. During the past three decades, significant efforts have been made to develop more practical and affordable designs for stationary power applications, but progress has been slow. Today, the most widely deployed fuel cells cost about $4,500 per kilowatt. By contrast, a diesel generator costs $800 to $1,500 per kilowatt, and a natural gas turbine can cost $400 per kilowatt or even less.

5.2 Alternative Fuel and Energy Sources

Political, economic and environmental concerns are changing the way the U.S. looks at fueling vehicles. Consequently, exploration of alternative energy sources is increasing. The transition to alternative fuels for cars and trucks is motivated by three important considerations:

a. Alternative fuels generally produce fewer vehicle emissions that contribute to smog, air pollution, and global warming;

b. Most bio-derived alternative fuels are not produced from finite petroleum-based-fuel resources;

c. Alternative fuels can help a nation become more energy independent.

The Role of Renewable Energy Consumption in the Nation's Energy Supply, 2007[31]

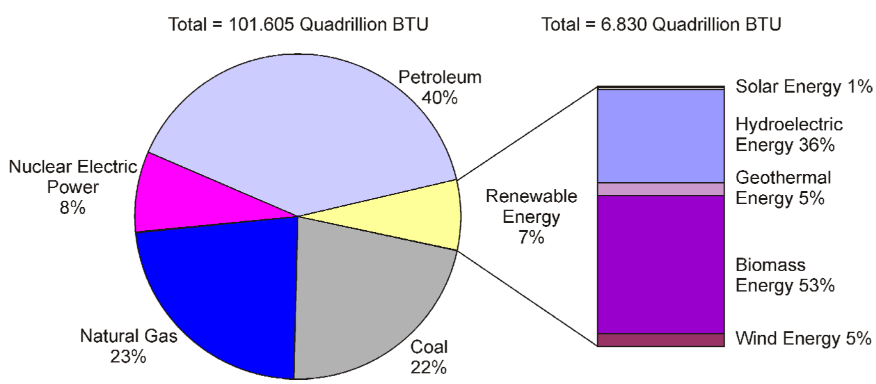
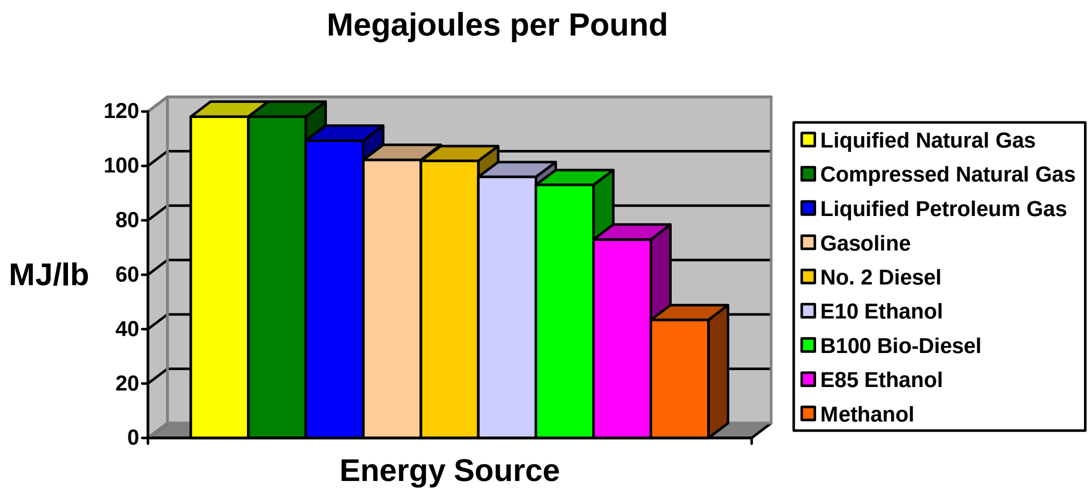


Figure 5-1. Role of Renewable Energy Consumption in the Nation's Energy Supply.

5.3 Energy Standards

Energy standards set minimum required performance levels against which we need to assess each energy option for its suitability for tactical equipment and compatibility with the other services. Each option considered is measured against the following three criteria: Accessibility - the degree to which a product (e.g., device, service, and environment) is accessible by as many people as possible; sustainability - the ability to maintain a certain process or state; and affordability - the extent to which something is affordable, as measured by its cost, relative to the amount that the purchaser is able to pay. As a frame of reference, the chart below illustrates the energy density of various fuels which serves as a measuring stick for each option considered.

[31] Found on DoE website: http://www.eia.doe.gov/fuelrenewable.html.



Note: The figure for electricity was derived by calculating the kWh of electricity produced by one gallon of diesel fuel when used in a U.S. Army generator, using the factor of 0.97 gallons of diesel fuel per hour to produce 10 kWh.

Figure 5-2. Comparison of Energy Content of Various Fuels.

Chapter 6: Future Pursuits and Metrics

It is vital to the success of this strategy that the DoD develops energy-related metrics that measure both the pace and success of specific projects and initiatives, and to capture aggregate progress in integrating energy factors in the DoD. Both are required, but project implementation metrics (fulfillment of schedules, ensuring resources are applied as planned, outcomes track with plans, etc.) are simpler and responsibility for reporting is more easily assigned than for the broader issues. While the various DoD and Army energy oversight groups should track and aggregate such progress on specific programs or initiatives, it is vital that the mainstream processes and organizations that perform all the typical services of the DoD incorporate energy-related factors and metrics into their normal work. This would include assessing how fuel demand cost and fuel delivery risk is being considered in DoD force planning, requirements development, and acquisition processes and programs[32].

A critical part of establishing metrics is setting baselines, as well as setting targets and thresholds, against which to measure progress. This strategy has led us to develop some initiatives to pursue for the near, mid, and long terms. It will be critical for the Army to establish near-term and mid-term pursuits to lay the foundation for the long-term solutions. The Tactical Fuel and Energy Strategy for the future Modular Force will assist in defining the strategy we will need to take beyond 2025. Metrics will be developed during the strategy and later refined for use in the Tactical Fuel and Energy Plan for the Army to implement[33].

6.1 Near-Term Pursuits 2009-2015

- Establish a single Army office to manage tactical fuel/energy requirements and initiatives
- Increase tactical fuel/energy conservation, awareness, and implement cultural change
- Operationalize and institutionalize small business practices, goals, and performance metrics
- Develop “bridging” fuel saving measures
- Pursue development of alternative energy sources/ultimate fuels (R&D 6.3) for tactical use
- Pursue R&D with goal of energy security and tactical petroleum-based fuel independence
- Establish tactical fuel and energy dialogue with Joint/Coalition partners

6.2 Mid-Term Pursuits 2015-2025

- Redesign Force Structure/Distribution systems to accommodate alternative energy sources/alternative fuels
- Update goals to increase tactical fuel/energy efficiency
- Revise TTP to leverage increased mobility/survivability on battlefield
- Continue to pursue R&D with goal of energy security and total petroleum-based fuel independence

[32] DoD Energy Security Strategic Plan (ESSP), Volume I: Strategic Plan, November 2008.
[33] ibid.

- Formalize tactical fuel and energy practices with Joint/Coalition partners

6.3 Long-Term Pursuits 2025 and Beyond

- Update goals to increase tactical fuel/energy efficiency
- Continue to pursue R&D with goal of energy security and total petroleum-based fuel independence
- Achieve total fuel and energy interoperability with Joint/Coalition partners

In some cases, establishing baselines will require new analyses and historical case studies to be established to provide a context for comparison. For tactical vehicles, some new analysis may be required to determine how much the fuel demand from a Future Combat System vehicle would need to be reduced to meaningfully reduce the size of the delivery tail.

The DoD Energy Security Strategic Plan (ESSP) was formally signed by USD (AT&L) and Vice Chairman, Joint Chiefs of Staff (VCJCS) in January 2009. Goal four of the ESSP calls for the development of DoD energy goals and metrics. As these goals and metrics are developed by the Office of the Secretary of Defense (OSD) and the Joint Staff, the Army's energy goals and metrics will have to be aligned with DoD efforts[34].

A Metric Matrix (Appendix C) has been developed offering some objectives and metrics as a means of determining if we are making progress toward achieving our goals. Consistent with Army guidance for installations, the tactical Army should strive for a similar reduction of 25 to 30%. This should be achievable through training, economical fleet management practices, pursuing a comprehensive energy awareness program, further development of intelligent power initiatives, and establishing a sound fuel/energy accountability and management system. If the Army could accomplish this reduction, it could free up almost $1 billion at the current fully burdened fuel cost and consumption levels. With the tactical component accounting for approximately 45% of the current overall Army consumption, the savings could be $500 million or more annually. This savings could be applied to materiel modifications and/or new, more economically efficient systems/platforms. This could be reasonably accomplished through a modest 2% reduction in consumption per year starting in 2010.

Appendix C depicts 13 objectives that support two or more of the goals of this study. The objectives are interim steps or means to make progress on the study goals. The goals themselves are open-ended, and by their structure can never be completed, which makes it even more important to develop and track metrics to show progress toward them.

The matrix lists the objectives first followed by the primary entity that can measure the progress toward the objective. The key performance indicator shows what is being measured. The metric column depicts what the key performance indicator is being measured against. The last two columns list the timeframe expected to see significant progress for the metric and the goals that the objective supports.

[34] Information furnished by the OSD, teleconference call from CASCOM and OUSD (AT&L) SSE/DT&E, 12 March 2009

Chapter 7: DOTMLPF Analysis

7.1 DOTMLPF Analysis

Army planners identified several goals and focus areas that were used in the development of this Tactical Fuel and Energy Strategy for the future Modular Force. The study group conducted an analysis to determine whether an integrated Doctrine, Organization, Training, Materiel, Leadership and Education, Personnel, and Facilities (DOTMLPF) approach would address the overall study objectives. In order to do this the team employed high-level DOTMLPF analyses and evaluated the impact of adopting the proposed near-, mid-, and long-term pursuits outlined in Chapter 6, supported by the findings and recommendations in Chapter 9.

7.2 Objective and Scope

A DOTMLPF analysis is normally developed to identify specific solutions to gaps that have been identified in a Functional Need Analysis (FNA). This preliminary DOTMLPF analysis has been conducted at a conceptual level to explore potential impacts of implementing proposed solutions advocated in the Tactical Fuel and Energy Strategy. Until specific solutions and implementation strategies are developed through a functional solutions analysis, a complete DOTMLPF analysis cannot be achieved with actionable results. There is a broad range of options that are being considered, however no single solution set is being proposed at this time. Ultimately, the Army must adopt solutions that are affordable, militarily useful, and supportable by the combatant commanders. The intent is to develop integrated, joint-capable solutions within the domains of DOTMLPF. Chapter 7 contains a list of the near-, mid-, and long-term pursuits. This analysis examines where we are, where we want to be, what risks we may face, and what it might cost. Table 7-1 shows how the pursuits apply to DOTMLPF domains. The collaborative nature of this effort is meant to develop potential solutions in an integrated fashion that reflect the future requirements. The integrated DOTMLPF implications of any proposed materiel solution must be considered throughout the process.

7.3 Qualitative Analysis and Findings

The analysis determined that the goals of the proposed Tactical Fuel and Energy Strategy for the future Modular Force could only be met with a combination of solution sets across the DOTMLPF domains. DOTMLPF domains were examined, and the impact of adapting the proposed strategy noted. Although there is some overlap with the study findings and recommendations, the DOTMLPF analysis attempts to go a level deeper into the types of actions that must occur to attain the goals listed in the study. Table 7-1 summarizes the actions and relates each action to the DOTMLPF domains that are applicable. Table 7-2 lists tasks and objectives that support the goals of the study and relates them to the DOTMLPF domains that are applicable.

7.4 DOTMLPF Domain Descriptions and Assessment

7.4.1 ***<u>DOCTRINE:</u> The way we fight and sustain the force, e.g., emphasizing maneuver warfare combined air-ground campaigns.***

Implementation of the proposed solutions could have a moderate impact on doctrinal publications.

Proposed fuel and energy reduction initiatives do not add any new capabilities, but rather employ technology to introduce greater efficiencies. Changes to regulations and field manuals would be minimal and could be incorporated during the normal publication update process. However, the introduction of alternative fuels may require changes to the current fuel distribution system. These changes must be communicated to Leaders and Soldiers unilaterally through revised

regulations and field manuals. Changes will impact not only fuel and distribution manuals, but also the logistics support portions across all doctrine.

7.4.2 ***ORGANIZATION**: How we organize to fight and sustain the fight.*

Implementation of the proposed solutions would have minimal impact on Table of Organization & Equipment (TOE) organizations.

An initial assessment indicates that the proposed solutions would require neither new organizations, nor authorization for additional personnel to be added to current organizations. The basic mission and capabilities of military units would not be significantly impacted. Equipment authorizations would have to be updated, but new equipment would generally be introduced to the units as modifications to existing equipment or one-to-one exchange for modernized, fuel/energy-efficient equipment.

7.4.3 ***TRAINING**: How we prepare to fight tactically and sustain the fight.*

Implementation of the proposed solutions would have minimal to potentially moderate impact on institutional training.

An initial assessment indicates that adopting the proposed solutions would require neither new Military Occupational Specialties (MOS) nor any major changes to the institutional training base (basic training to advanced individual training). Adopting the proposed solutions may require a re-work of existing fuel operations Programs of Instruction (POI) to accommodate the training for operating new alternative fuel equipment and adopting new delivery methods. The introduction of a FMD system to ensure fuel accountability will require some additional training. Since incorporation of alternative fuels will be accomplished incrementally, training will need to continue for both traditional fuel and alternative fuel skill sets. A focused, across the board campaign to affect a cultural change for energy awareness must be incorporated into training at every level. This will also include leader development and unit level collective training. The recommended energy awareness training could be integrated into leader development and unit level collective training. System-specific training could be integrated into the school house’s current Programs of Instructions (POI).

7.4.4 ***MATERIEL**: All equipment and supplies necessary to provision our forces so they can operate effectively.*

Implementation of the proposed solutions would require a major investment in new fuel and energy technologies.

While the basic equipment requirement would remain unchanged, in order to reach the fuel and energy reduction goals, new technologies must be introduced into the military system. Many of the new alternative fuels currently being evaluated are materiel solutions, which could be categorized into two types: equipment that features technology that reduces consumption and equipment that uses alternative fuels in place of petroleum-based fuels.

New emphasis on reducing fuel/energy costs will change the way all materiel is evaluated for acquisition. As of 7 January 2009, all new Army acquisition programs with end items that consume energy will include the Fully Burdened Cost of Fuel (FBCF) needed to operate the system in their total ownership. The FBCF is the fuel commodity price plus the total life cycle cost of all people and assets required to move and protect fuel from the point-of-sale to the end user. This new view of the “hidden” cost of fuel will have to be instilled at all levels of Army leadership.

Some types of alternative/renewable fuels/energy may require special equipment, special storage requirements, and/or transportation for distribution. These items, if any, will be determined under the follow-on implementation plan.

7.4.5 *<u>LEADERSHIP AND EDUCATION</u>: How we prepare our leaders to lead the fight.*

Implementation of the proposal solutions would require a change in the leadership culture. Tactical leaders must be trained to value efficiency.

A successful Army energy program requires both centralized and decentralized leadership with the appropriate authority and support to lead the entire Army energy program. Changing the culture of the Army to one that prioritizes efficient energy utilization will require the leadership to integrate current projects and efforts with new and improved energy security proposals. This will be accomplished by holding Army commands, offices, and personnel accountable for their energy programs and by providing incentives for innovative energy solutions. The Army should incorporate fuel and energy reduction into its Warrior and leader training as well as training for the Army Acquisition Corps.

7.4.6 *<u>PERSONNEL</u>: Availability of qualified people for peacetime, wartime, and various contingency operations.*

Implementation of the proposed solutions would have a minimal to moderate impact on personnel.

An initial assessment indicates that adopting the proposed solutions would not require any new MOSs or create requirements for additional personnel authorization in TOE organizations. Skill identifiers may be needed to support new technologies. Establishment of the proposed Tactical Energy Office would require staffing and resourcing.

The introduction of alternative fuels may require a shift in MOS responsibilities. Alternative fuels require different skill sets to operate/maintain equipment than JP 8 fueled equipment. This may require the introduction of a new MOS, or a change to an existing MOS (moderate impact). If an MOS change is not required, a skill identifier may be employed to satisfy this requirement (minimal impact).

Future fuel efficient engines may be considerably more complicated in their control, incorporating such additional technologies as exhaust gas recirculation, variable geometry turbo charging, variable valve timing, multiple injection strategies, and exhaust gas after treatment. More complicated engines will require new skills to be learned by wheeled vehicle mechanics.

7.4.7 *<u>FACILITIES</u>: Real property; installations and industrial facilities that support our forces.*

Implementation of the proposed solutions may have a moderate impact on facilities used to store fuel products and to temporarily house Soldiers.

If special storage requirements and/or environmental considerations arise, it may impact both garrison and field operations. A follow-on evaluation must be conducted to determine requirements associated with each fuel alternative. If multiple fuels are stored and deployed to the operational area, an increase in the facility requirement can be expected.

Table 7-1. Near-, Mid-, and Long-Term Pursuit Applicability to DOTMLPF Domains.

Near-Term Pursuits Present-2015	**DOCTRINE**	**ORGANIZATION**	**TRAINING**	**MATERIEL**	**LEADERSHIP & ED**	**PERSONNEL**	**FACILITIES**
Establish a single Army office to manage tactical fuel/energy requirements and initiatives	■	◘	◘		◘	◘	◘
Increase tactical fuel/energy conservation awareness and cultural change	◘		■		■		
Operationalize and institutionalize small business practices, goals, and performance metrics	■				◘		
Develop “bridging” fuel saving measures	◘		◘	◘	◘		
Pursue development of alternative energy sources/alternative fuels (R&D 6.3) for tactical use				■			◘
Pursue R&D with goal of energy security and tactical petroleum-based fuel independence	◘			◘			
Establish tactical fuel and energy dialogue with joint/coalition partners	◘				◘		
Mid-Term Pursuits 2015-2025							
Redesign force structure/distribution systems to accommodate alternative energy sources/ultimate fuels	◘	◘	◘	■	■	◘	◘
Update goals to increase tactical fuel/energy efficiency	◘		◘		◘		
Revise Techniques, Tactics, and Procedures (TTP) to leverage increased mobility/ survivability on battlefield	■		■		■		
Continue to pursue R&D with goal of energy security and total petroleum-based fuel independence	◘			◘			
Formalize tactical fuel and energy practices with Joint/Coalition partners	■				◘		
Long-Term Pursuits 2025 and Beyond							
Update goals to increase tactical fuel/energy efficiency	■		■		■		
Continue to pursue R&D with goal of energy security and total petroleum-based fuel independence	◘		◘	◘	◘		
Achieve total fuel and energy interoperability with joint/coalition partners	■				◘		

Applicable = ■
Partially Applicable = ◘

Table 7-2. Enabling Tasks and Supporting Objective Applicability to DOTMLPF Domains.

Enabling Tasks and Supporting Objectives	**D** OCTRINE	**O** RGANIZATION	**T** RAINING	**M** ATERIEL	**L** EADERSHIP & ED	**P** ERSONNEL	**F** ACILITIES
Apply Fully-burdened Cost in Conducting Distribution Analysis	◘		◘	◘	◘		
Develop a Comprehensive Fuel/Energy Accountability and Management System	■		■		■		
Develop Effective Test and Certification Protocols to Approve Alternative Fuels.	◘		◘	◘	◘		
Develop Energy Awareness Program	◘		◘		◘		◘
Develop Fleet Management Program	◘		◘		■		◘
Develop Fuel Efficiency Standards	■				◘		
Develop Fuel Efficient Engines			◘	■			
Develop Intelligent Power Distribution Systems	◘			■		◘	◘
Develop Weight Reduction Program for Tactical Vehicles	◘		◘	■	◘		◘
Enforce/Implement Predominant Fuel on the Battlefield	■			■			◘
Identify Requirements for Unique Facilities to Accommodate Alternative Fuels				■			■
Pursue Development of Simulators			■	◘			■
Pursue the Development of Alternative Fuel and Energy Sources	◘			■			

Applicable = ■

Partially Applicable = ◘

Chapter 8: Joint Operations

Future operations are more likely to be decisive if they confront an enemy simultaneously on multiple lines, in multiple ways, and against multiple points of vulnerability. Future combatant commanders will need to conduct integrated strike, maneuver, and information operations with powerful joint and interagency teams of ground, space, maritime, air, and Special Operations Forces (SOF). Such teaming greatly multiplies the combat power of each component, deprives the enemy of the freedom to focus his own efforts, overloads his planning and coordination mechanisms, and compels him to expose his forces to new threats in the effort to evade.[35]

By virtue of their inherent versatility, land forces provide the joint force commander the broadest set of options and permit the most discriminate application of force over space and time. This modulating quality is particularly important in smaller scale contingencies, in which the commander must be able to balance destruction with control and lethal effects with nonlethal effects.

OSD, the Joint Staff, and the military services have undertaken efforts to reduce tactical fuel and energy demand in weapons platforms and other mobile defense systems:

- The Joint Staff updated its policy governing the development of capability requirements for new weapons systems to require that energy efficiency be considered as a key performance parameter.[3]
- The Army is addressing fuel consumption at Army base camps by developing foam-insulated tents and temporary dome structures that are more efficient to heat and cool, reducing the demand for petroleum-based fuel-powered generators. Another initiative is the development of a transportable hybrid electric power station, which uses wind, solar energy, a diesel generator, and storage batteries to provide reliable power with fewer fuel requirements[36].
- The Navy has established an energy conservation program to encourage ships to reduce energy consumption. The program provides training materials, such as a shipboard energy conservation manual and a pocket guide to assist commanders with energy-saving activities. The program also gives quarterly awards to ships that use less than the Navy's established baseline amount of fuel. It has also made ship design alterations to reduce fuel demand.
- The Air Force has identified and begun to implement initiatives aimed at reducing mobility energy demand and increasing fuel efficiency, aligning these initiatives with its energy strategy. These initiatives include determining fuel-efficient flight routes, reducing the weight on aircraft, optimizing air refueling, and improving the efficiency of ground operations. In addition, it is testing synthetic fuels in its aircraft that could partly displace the use of petroleum-based fuel.
- The Marine Corps has initiated research and development efforts to develop alternative power sources and improve fuel management. For example, it is testing the use of hybrid power—by combining solar panel, generator, and battery energy sources—at remote sites to lessen its fuel transportation demands to forward-deployed locations.

While these and other efforts are underway and the DoD has identified fuel and energy as one of its transformational priorities, the Department lacks elements of an overarching organizational framework to guide and oversee tactical fuel and energy reduction efforts. In the absence of an encompassing organizational framework for tactical fuel and energy, the DoD cannot be assured that its current efforts will be fully implemented or will result in a significant reduction of its reliance on petroleum-based fuel.

[35] TRADOC Pam 525-3-0, V2.0, the Army in Joint Operations, 7 April 2005.
[36] GAO-08-523T, Defense Management: Overarching Organizational Framework Could Improve DoD's Management of Energy Reduction Efforts for Military Operations, 13 March 2008, pgs. 7 & 8.

It is imperative that the Army remain synchronized with the fuel and energy transformation of the other services to ensure alternative energy sources and infrastructure support Army requirements.

Chapter 9: Findings and Recommendations

Analysis of the information provided in the previous chapters led to the following set of findings and recommendations.

Finding #1: Petroleum-based fuels will remain the Army's main power source for tactical platforms from now until the 2024 timeframe, the timeframe for this strategy, and beyond. However, alternative fuel and renewable energy options are rapidly maturing to a point where integration of several of these options are viable for tactical military operations.

With only 2% of the United States' energy requirements being driven by the DoD, any major shift in the supply of petroleum-based fuels and energy at the national level will be an economical decision based on the global economic environment. The U.S. Army will remain primarily dependent on petroleum-based fuels for tactical operations from now until the 2024 timeframe encompassed by this study. As long as petroleum-based fuels are less expensive than other fuel or energy sources, this nation will continue to focus on the use of petroleum-based fuels. As alternative fuels and other energy sources become economically competitive with petroleum-based fuel, then a shift will occur. This shift will have to be preceded by a major investment in our infrastructure that is associated with alternate fuel/energy production.

There are a number of evolving and viable alternative energy options that can be further researched and developed for integration into tactical equipment platforms to supplement petroleum-based fuels and thereby decrease petroleum-based fuel requirements. The Army can stage itself through additional and increased R&D efforts to implement these alternative energy options when economics and operational imperatives allow for their incorporation. This shift will likely occur in advance of any major shift in our civil sector due to incorporation of the fully burdened cost of bringing petroleum-based fuels to the combatant commander as a driving factor and the need to reduce the logistical footprint of forces supporting combat operations of the Modular Force.

The two primary power-producing components in our combat systems, the turbine engine and the internal combustion engine, are at the heart of our dependence on petroleum-based fuels. Any significant reduction in our petroleum-based fuel dependence must focus on alternate fuels and energy sources that can effectively produce a similar level of power. The implementation of alternative energy options may directly translate into many combat multipliers. These could include a reduction in logistical soldiers and equipment in the battle space, increased operational and tactical flexibility, greater security through decreased dependence on external resupply, decreased maintenance requirements on internal combustion engines, increased operational readiness rates, and decrease in funds required to resupply petroleum-based fuel. Each of these changes would require comprehensive cost-benefit analyses to ensure that any trade-off to alternative fuel/energy sources provide a positive return across a multitude of considerations including cost, operational feasibility, lift requirement, energy value, and maintenance impacts.

Recommendation #1: Alternative fuel and renewable energy solutions should be researched and developed on an aggressive timeline for implementation to the degree possible in the future Modular Force.

Alternative fuel and renewable energy solutions should be developed to supplement petroleum-based fuel requirements. While these can lessen the amount of petroleum-based fuels required, they will not be able to replace petroleum-based fuels by the year 2024. This is driven by a number of factors to include the fuel-burning nature of the equipment platforms we currently use to conduct wars, the current buys of new equipment to conduct war for the next 20-40 years, the national and the global fuel production base, the national and global economy, and that major energy exploration and production emphasis is still heavily focused on petroleum-based fuels. It should also be noted that while petroleum-based fuel requirements may be decreased, total fuel

requirements and throughput may increase if the replacement alternative fuels/renewable do not provide the same energy output as current fuels, e.g., some replacement fuels may not have the same gallon-for-gallon replacement value due to lower energy efficiency. The degree to which alternative energy can be integrated into tactical operations is dependent on the spectrum of conflict, the maturation of the alternative energy options, and the economic feasibility of moving from the traditionally low cost of petroleum-based fuels. There are three major power platform categories that produce power for the U.S. Army's tactical force; these are turbine engines, internal combustion engines in tactical vehicles, and internal combustion engines in power generators. The most promising options are alternative fuel blends for the power platforms previously mentioned, advanced hybrid electric power systems (a combination of an internal combustion engine and electrical power) on ground vehicle platforms, and a combination of solar energy coupled with intelligent power management for power generation equipment.

The long-term military strategic path for the United States should focus our primary Warfighting alternative fuel production on coal-based fuel. This nation's largest energy reserves are in coal. The United States has more recoverable coal reserves than any other nation[37]. The ability for the U.S. to independently develop and produce fuel from our vast wealth of coal reserves directly contributes to an enhanced security posture. However, the U.S. Army will not be able to dictate this national shift. Instead, the Army should prepare for the day that adoption of coal-based fuels is economically and operationally feasible. The U.S. Army should leverage the R&D being conducted by the other services such as the Air Force on the use of FT-produced liquid fuels. These liquid fuels are derived from coal and are being successfully tested in major U.S. Air Force airframes in a 50-50 blend with JP8. Likewise, the U.S. Army should conduct tests with turbines and engines found in the Modular Force tactical platforms to assess the viability for use of these future alternative fuels. These tests should span an array of blends to determine the optimal blend for maximum performance. The transition is not likely to occur between now and the 2024 timeframe of this study. The shear costs of transforming our petroleum-based fuel production base, in our nation and around the globe, will make this option uneconomical in the global community for some time. There are also significant environmental issues under increasing legislative scrutiny which may impact on the ability to transition to these energy sources. Countries such as China are already investing billions of dollars internally to begin this shift in production capabilities, and South Africa has already successfully made this leap in their South African Synthetic Oils (SASOL) facilities where they produce jet fuel using the FT process. The SASOL jet fuel is approved for commercial airline use and is officially classified as Jet A-1 fuel[38]. The United States will likely make this shift one day in the future and the U.S. Army needs to be prepared for that day.

Advanced hybrid electric power systems are well within the 2024 timeline for incorporation into the Modular Force. The development of and commitment to hybrid electric architecture for tactical wheeled vehicles may reduce overall fuel consumption, however, additional analysis would be required to ensure any shift to a hybrid platform would not hinder current operational capability. Prototype systems have already been developed and show very promising results. As previously stated, the diesel hybrid engine can provide reductions of 20% or more in light duty vehicles. Army tactical vehicles are dependent on the engines being designed for the Army's mission profiles and require more study for definitive results. Various alternative fuel options are being developed but have not reached the level of maturity needed to sustain the tactical force in the near term. The use of lightweight metals and/or composites to make systems lighter while maintaining current capabilities associated with the system is technologically possible and feasible now.

Renewable energy resources such as solar energy and its use with power generation platforms with intelligent power form an alternative energy solution for the power platform category. Detailed discussions on power generators are discussed below in Recommendation #2.

[37] www.eia.doe.gov/oiaf/ieo/coal.html
[38] www.redorbit.com/news/business/1334179/sasol 100 synthetic fuel wins first time approval for use/index.html

None of the recommendations outlined above should be implemented in isolation. Each must be considered as part of the total solution set and evaluated with the pros/cons of other viable options. The optimum solution set will continue to evolve as technology developments provide alternatives to current petroleum-based fuels. Although a replacement fuel/energy source may not be viable today, the same source may demonstrate considerable efficiencies over the next few years making it a much more desirable energy source for tactical use consideration.

Finding #2: Decreases in petroleum-based fuel use for power generation equipment are feasible in the near term with technology solutions that are currently available or evolving.

U.S. Army power generation equipment comprises the largest consumer commodity of petroleum-based fuels on the battlefield as discussed in Chapter 4 of this document. As such, any actions that can be taken to decrease the use of petroleum-based fuels in this arena will have a noticeable impact on lessening the tactical Army's overall petroleum-based fuel requirements. The primary power-related function of these generators is to provide electrical power for various equipment items and for cooling/heating of living and work spaces. Most of these generator sets are placed in TOEs based on initial organization designs with each operating section receiving its own generator, based on usage requirements. Typical operational environments will primarily involve the use of these generators in stationary operations such as at Forward Operating Bases (FOB) or remote locations. This usage profile opens the options up to a combination of renewable energy solutions, intelligent power, and other measures, such as the use of camouflage systems that block solar loading.

Recommendation #2: Invest in the development and fielding of solar solutions and other alternative energy sources to supplement existing power generation systems and in an intelligent power program to centrally manage power-generation platforms in base camp-type locations.

Renewable energy resources are getting closer to being capable of providing a viable energy source to tactical forces. Specifically, solar energy can be applied for power generation. By no means will current solar technology replace existing power generation capabilities, however it may be used as a potential backup power source and should remain a potential option for continued development and use. Future improvements in technology and significant price drops in fundamental solar panel components, such as polysilicon, may bring solar power into the realm of operational feasibility during the time frame covered by this strategy. While solar energy cannot compete with the low price of petroleum-based fuels in our civilian sector for some time, the fully burdened cost of fuel in tactical operations may make solar energy a viable and realistic energy source in a multitude of tactical operations. For those locations where solar energy may not be the best option, a concerted effort to efficiently use available generator power must be continued and should address efficiencies to avoid issues such as generators operating well below their rated capacity. This in turn can lead to poor engine performance, excessive fuel consumption, and possible engine failure.

Likewise, evolving initiatives such as intelligent power open the option to more efficient use of the various power-producing platforms in such places as operating bases. The focus of intelligent power is on the overall power management of the power generated and used inside a particular footprint through the use of a central power grid. There are pros and cons to this concept and the Army has taken the next step through the award of several contracts to develop the necessary software and components to allow for prototype testing. Based on a brigade-level model, the new power management system has a potential fuel savings of more than 50 percent, according to an estimate by the Army's Communications-Electronic Research, Development and Engineering Command[39].

[39] National Defense Magazine, Army Powers up for Ambitious Fuel Saving Program, April 2008

Coupling renewable energy and intelligent power with reduced solar loading can even further reduce energy needs. The use of the Ultra Lightweight Camouflage and Netting System (ULCANS) in hot climates, such as the desert, can significantly reduce solar loading on personnel and equipment placed under these netting systems. ULCANS not only hides our soldiers from enemy observation, it hides the operating space from solar loading. Any power-generation equipment used for cooling purposes would be doing so under a reduced solar load which, in turn, translates to reduced fuel usage.

The Army should coordinate efforts and partner with other services to leverage technologies that may reduce generator fuel consumption. For example, the Air Force's deployable shelters powered by solar and fuel cell generators. The Air Force is also engaged in other projects using fuel cell, biofuel, and other renewable or alternative energy technologies which the Army could partner with for mutual benefit. The Marine Corps has a Deployable Renewable Energy Alternative Module which is towed by a vehicle and is designed to provide power for radios or computers by employing solar, wind turbine, battery, or generator technologies.

Finding # 3: Current tactical planning and mission execution does not consider fuel and energy conservation.

Throughout the research of this strategy, there seemed to be a common theme when addressing fuel/energy conservation – it was neither required nor valued. "Although significant war fighting, logistics and cost benefits occur when weapons systems are made more fuel-efficient, these benefits are not valued or emphasized," in any of the services, the Defense Science Board, the Pentagon's most prestigious technical advisory panel, concluded in 2001.[40]

The Army has never truly been constrained by a lack of fuel or energy resources when planning or executing combat operations, therefore a savings mindset has never been incorporated into the Army's culture. Fuel reduction is simply not a major consideration in training or planning efforts. Commanders and planners normally focus on direct combat actions without any major consideration on how to reduce the liquid logistics tail. There is no institutional mindset across the Army to consider fuel/energy reduction efforts when planning for tactical operations.

The "Single Fuel on the Battlefield" concept was designed to reduce the logistics footprint by reducing the multiple fuel grades transported/stored/issued at the same location. The concept was never truly implemented in practice as evidenced by the number of fuel grades currently in use on the battlefields in Iraq and Afghanistan. Support contracts have not always included a requirement for sustainment operation equipment to be JP8 (single fuel) capable. This further exasperates any attempt to move to a single fuel. Finally, the support of coalition forces with non-JP8 capable equipment may not always allow for full implementation of a single fuel concept. Although the goal of a single fuel may not be 100% achievable, a significant reduction in multiple fuel grades (gasoline and diesel fuel specifically), and the associated support footprint, could be realized resulting in significant efficiencies when transporting and storing these commodities.

Recommendation #3: The Army should institutionalize fuel/energy savings procedures and concepts across all levels. Every effort must be made to reduce the number of fuel grades required on the battlefield.

A shift in Army culture regarding energy is required and the Army must institutionalize the concept of fuel/energy savings across all levels. Army leaders at all levels must be trained to recognize or create opportunities to conserve energy and be prepared to exploit them.

Any contractor support equipment on the battlefield must be capable of using the predominant fuel available in the area of operation; this requirement should be included in all contracts.

[40] Defense Science Board Task Force Report, October 2001.

Although this may require an additional up-front cost for the use of multi-fuel equipment, it will also allow the Army to move closer to a single-fuel realization thereby gaining efficiencies in other areas (transportation, storage, and distribution). Where possible, coalition forces must use the predominant fuel available on the battlefield. Future developments may allow the predominant fuel on the battlefield to include alternative fuels and these options must be taken into consideration when developing support options.

This recommendation may conflict with several others in this study to pursue alternative fuel options. In each case a thorough trade-off analysis is required to weigh the overall effect of a course of action.

Finding #4: The Army does not have an automated asset visibility tool for fuel which in turn leads to an inability to accurate reflect on-hand totals or future requirements on the battlefield.

The ability to see the total fuel picture in the battle space in real time, combined with the ability to dynamically reallocate petroleum assets as combat operations evolve can greatly improve the efficient delivery of this scarce and critical resource. In addition to contributing to sustained operational tempo and extending operational each, the number and frequency of fuel convoys/sorties could also be reduced, with a corresponding reduction in the vulnerability of these assets and the number of soldiers pulled from other duties to protect them. The most important part of this process is the total visibility that will be made available to commanders at all levels.

Current asset visibility for fuel on the battlefield requires manual data collection and reporting. This lack of real-time information does not allow commanders or planners to accurately determine on-hand totals or resupply requirements. The end result is a resupply effort which often overestimates the true requirement, thereby requiring more fuel than really necessary to meet stockage objectives. Compounded across multiple storage sites, the results are additional storage requirements and distribution assets for increased levels of fuel.

Follow-on to the lack of asset visibility is the inability to accurately account for fuel at tactical locations. Without such a capability, the Army will never be able to accurately track fuel consumption or properly account for fuel on the battlefield.

Recommendation #4: The Army should continue efforts toward field automation to allow for both asset visibility and accountability of fuel on the battlefield.

The Army must continue efforts to field an automated accountability system for fuel on the battlefield. This system would allow commanders to view near real-time information regarding fuel on-hand and consumption trends. At a higher level, this data would be used to meet forecast requirements while considering realistic on-hand totals. In total, this view of on-hand fuel assets would allow for tailored resupply focusing efforts to meet demand without building excessive stockage levels.

Finding #5: Petroleum-based fuel supply interruptions will be greater in the future as global demand increases and global supply decreases.

Our nation's wars will continue to be waged on other continents. Extended lines of communications from our CONUS bases and less petroleum-based fuel availability in the future to meet global demands raise the probability of shortfalls in the supply of petroleum-based fuels to our fighting forces.

Our OCONUS fuel stocks are placed at geographical locations that provide strategic fuel storage. These stocks are maintained to meet our wartime requirements (PWRMS) and our peacetime (POS) requirements. The quantity stored is based on fuel requirements and the number of days

of supply that must be maintained before resupply can be accomplished. Global demand for petroleum-based fuels will only increase with time and the industrialization of countries such as India and China. As such, it should be anticipated that in the next decade our ability to keep stocks resupplied in the same amount of time as is done today is questionable. An increase in the storage level of fuel stocks can mitigate this gap.

Recommendation #5: Increased storage requirements should be considered in OCONUS locations for our Prepositioned War Reserve Material Stocks (PWRMS) and Peacetime Operating Stocks (POS) of fuel.

Our OCONUS fuel stocks are placed at geographical locations that provide strategic fuel storage to meet wartime and peacetime requirements. As global demand for fuel increases, and petroleum-based fuel production decreases, the relative shortage poses an increasing supply risk. We can mitigate this risk by maintaining current levels of PWRMS and POS of fuel; continuing to partner with other countries to purchase and store fuel; and investing in research and development for modernizing fuel consuming vehicles and equipment and introducing alternative and renewable sources to reduce reliance on and consumption of petroleum-based fuels.

Finding #6: The Army does not have a single office designated to address all tactical fuel and energy issues to maintain the operational visibility during the global energy evolution.

The Army has recently established several levels of oversight to guide energy security issues as outlined in the Army Energy Security Implementation Strategy[41]. However, there remains no single office/point of contact designated to focus solely on tactical fuel/energy issues. This lack of a designated office results in multiple agencies/offices focusing on tactical energy efforts, but each within their specific area with limited synchronization across the Army.

Recommendation #6: The Army should consider establishing a Tactical Fuel and Energy Office to serve as the focal point and advocate for energy initiatives which support tactical deployment. This office would be charged to synchronize efforts across the Army while coordinating with the other services to ensure all efforts reflect the joint environment.

The Army should establish a single office to serve as the focal point and advocate for energy initiatives which support tactical operations. This office would serve as the primary advocate for tactical fuel/energy issues and solutions. It would be charged to synchronize efforts across the Army while coordinating with the other services to ensure all efforts reflect the joint environment.

The Office of the Deputy Assistant Secretary of the Army for Energy and Partnerships has been designated as the Army's single energy office. The Army Energy Security Implementation Strategy (AESIS), dated 13 January 2009, established the Army Senior Energy Council (SEC) to monitor the progress and receive reports from all across the Army on all energy matters. However, this strategy to date deals primarily with installations and contains only minor references to tactical mobility.

Current DA energy initiatives and frequently changing operational requirements necessitate a forum with tactical logisticians to advise and make recommendations to the senior energy council and the Army leadership. The Army needs a single focal point for all tactical fuel and energy actions. The Army should establish an overarching organizational framework for mobility energy to improve the Department's ability to guide and oversee mobility energy reduction efforts. To establish such a framework, the Army should designate an office to be accountable for mobility energy matters, develop a comprehensive strategic tactical energy plan, and improve the Army's business processes. The position must also have decision and tasking authority and an adequate

[41] Army Energy Security Implementation Strategy. Army Security Energy Council and the Office of the Deputy Assistant Secretary of the Army for Energy and Partnerships, Washington, DC. 13 January 2009.

staff and resources to address issues confronting the Army. Additionally, the office will establish policy for tactical equipment, as well as oversee the various ongoing projects across the width and breadth of the Army. Another very important aspect of the position is that the office must partner with other services as well as interface with industry.

The office would monitor tactical mobility fuels and energy logistics to exploit efficiencies and improve practices consistent with current and emerging Army and the DoD concepts and doctrine.

Finding #7: Fuel specifications for military use were originally developed solely for petroleum-based fuels. Specifications are currently being updated to include alternative fuels.

Alternative fuels were not a major consideration when the original fuel specifications were established for currently fielded tactical equipment. The introduction of alternative fuels as suitable products have, and will continue to provide, a requirement to allow for their use in tactical equipment thereby requiring changes to equipment specifications. Additionally, the storage stability standards of 36 to 48 months for petroleum-based fuels may be excessive based on the inclusion of alternative fuels as acceptable substitutes. Alternative fuels are currently being evaluated for use in tactical equipment and future equipment design must take alternative fuel options into consideration.

Recommendation #7: Reevaluate all applicable fuel standards to ensure the standards are still valid for today's global conditions.

Alternative energy fuels and petroleum-based fuels should be considered together in determining necessary standards that meet our needs today. The way we fight is changing, the world is changing, available resources are changing, and most importantly, technology is changing. Our standards also need to change with the times to ensure our services are benefiting from the best that can be made available. The Army should continue to evaluate alternative fuels for consumption in tactical equipment and modify equipment specifications to allow for the use of these fuels. Additionally, storage stability should be reviewed as alternative fuels are approved for use to ensure new fuels are addressed appropriately when long-term storage is a consideration.

Appendix A: Emerging Fuel/Energy and Power Source Options

Emerging Fuel/Energy Options

The list below summarizes alternative fuel/energy options that are emerging within the U.S. with the potential to reduce our dependency on foreign oil. It includes products that may be used as feedstocks. If one or more prove favorable for further exploitation, then efforts could be made to encourage industry to establish refineries to accomplish mass production. Various combinations of these fuel/energy types could reduce our dependence on foreign oil.

- **ALGAE** - Inexpensive culture systems using shallow (10 cm deep) ponds stirred with paddle wheels in areas of high solar isolation. Algae are a feedstock that can be used to produce refinable oil.

Item	Pro	Con
Algae	• Algae doesn’t compete with food/feed/ethanol • Much greater productivity than other bio feedstocks • Non-food resource • Use otherwise non-productive land • Can utilize saline water • Can utilize waste CO_2 streams • Can be used in conjunction with waste water treatment • Could produce oils, protein, and carbohydrates	• High capital and operating costs • Starting species (unknown) • Bio-fouling in closed systems environmental issues • Additives required • Engine testing required • ASTM standard not established

- **BATTERIES** –". An electric battery is a device that converts chemical energy into electrical energy, consisting of a group of electric cells that are connected to act as a source of direct current. Batteries store electricity in a chemical form, inside a closed-energy system. They can be re-charged and re-used as a power source in small appliances, machinery and remote locations.

Item	Pro	Con
Batteries	• Battery technology is safer, lighter, cleaner, and lasts longer with more power • No emissions • More efficient (less maintenance)	• Hard to transport in large quantities • Short operational duration • Expensive to replace

- **BIOBUTANOL** - Biobutanol is an alcohol that can be produced through processing of domestically grown crops, such as corn and sugar beets, and other biomass, such as fast-growing grasses and agricultural waste products. Biobutanol can be blended into standard grade gasoline or gasoline containing ethanol. It is compatible with existing vehicle technology and has the potential to be incorporated into the existing fuel supply infrastructure. Its energy density is higher than ethanol and methanol.

Item	Pro	Con
Biobutanol	• Renewable source • Compatible with the current gasoline and distribution infrastructure • Vehicles can be fueled with minor or no vehicle modifications • Energy density is higher than ethanol and methanol	• Energy content of biobutanol is 10 to 20 % lower than that of gasoline • Not fully tested

- **BIODIESEL** - Biodiesel is a domestically produced, renewable fuel that can be manufactured from vegetable oils animal fats, or recycled restaurant greases. Biodiesel is safe and biodegradable, and its use significantly reduces greenhouse gas emissions and serious toxic air pollutants.

Item	Pro	Con
B100 **(100% biodiesel)**	• Best for professional fleets with maintenance departments • Reductions in greenhouse gas emissions • Renewable resource • Higher lubricity than petroleum diesel • Higher flashpoint than petroleum diesel • Has 93% of the energy content of diesel • Domestically produced • Clean burning • No vehicle modification needed	• High Fuel Cost to produce (1 ½ times the cost of petroleum diesel) • Limited availability • Competes with food crops • Minor changes to storage & distribution equipment • Requires more energy to produce • Fails cold weather standards
B20 **(20% bio-diesel 80% diesel)**	• Can be used in most diesel engines • No change to most storage and distribution equipment • Lower emissions • Renewable resource • 99% of energy content as diesel • No vehicle modification needed	• Higher Fuel Cost than petroleum diesel • Limited availability • Competes with food crops

- **<u>BIOGAS</u>** - Biogas is the gaseous product of the anaerobic digestion (decomposition without oxygen) of organic matter such as animal manure, sewage, and municipal solid waste. It is typically made up of 50-80% methane, 20-50% carbon dioxide, and traces of gases such as hydrogen, carbon monoxide, and nitrogen. After it is processed to required standards of purity, biogas becomes a renewable substitute for natural gas and can be used to fuel natural gas vehicles.

Item	Pro	Con
Biogas	• Domestic, renewable resource • Reduces the cost of complying with U.S. EPA landfill gas combustion requirements • Produces sanitized compost and nutrient-rich liquid fertilizer • Substitute for NG • Waste is disposed of at the same time and in the same operation • Consumes methane, decreasing potential greenhouse effect • Can be used effectively on a small scale	• Explosive when mixed with air at 8-20 ppm • Initial higher installation, maintenance, storage, and distribution costs • Cannot provide electricity on a global scale • No controls exist on the rate of gas production

- **<u>BIOMASS</u> –** Any plant-derived organic matter. Biomass available for energy on a sustainable basis includes herbaceous and woody energy crops, agricultural food and feed crops, agricultural crop wastes and residues, wood wastes and residues, aquatic plants, and other waste materials including some municipal wastes. Biomass is a very heterogeneous and chemically complex renewable resource. Today, biomass resources are used to generate electricity and power, and to produce liquid transportation fuels, such as ethanol and biodiesel.

Item	Pro	Con
Biomass	• Renewable • Non-polluting. As long as fuel consumed is replaced with new crop, there is no net carbon emission.	• A large area of land is required for the production of fuel • Biomass cannot generate enough power to satisfy a global demand • Destroys organic matter so it cannot be returned to the land for soil improvement

- **<u>COAL TO LIQUID</u>** - Coal to liquid is a term describing processes for converting coal into liquid fuels such as gasoline and diesel. Currently, the major coal-to-liquids production process is the FT process, involving conversion of coal into gas and then into liquids. Several processes that convert coal directly into liquids (direct liquefaction) also exist. Coal, a fossil based fuel, is most often used because of its abundance in the U.S., but its conversion contributes to global warming by generating nearly twice the amount of carbon dioxide when compared to crude oil refining.

Item	Pro	Con
Coal to Liquid	• Large domestic coal reserves • Clean domestic liquid fuel production • Fuels produced are like Gas-to-Liquid (GTL) fuels and are compatible with existing liquid fuel infrastructure • Electric power by product	• Integrated operations of advanced CTL technologies have not been demonstrated • High capital/operation costs • Expansion of coal production and requisite infrastructure • High water use • CO2 & criteria pollutants emissions • Social resistance to coal use

- **COMPRESSED NATURAL GAS (CNG)** - CNG is a mixture of hydrocarbons, predominantly methane (CH_4). As delivered through the pipeline system it also contains hydrocarbons such as methane and propane and other gases such as nitrogen, helium, carbon dioxide, hydrogen sulfide, and water vapor.

Item	Pro	Con
CNG	• High octane rating and excellent properties for spark-ignited internal combustion engines • Non-toxic, non-corrosive, and non-carcinogenic • No threat to soil, surface water, or groundwater • Distribution network nationwide • Less wear on engine • Cheaper than gasoline	• Tanks are bulky & heavy • Less range • Vehicles are more costly

- **ETHANOL FUELS** - Ethanol is a renewable fuel made from various plant materials, which collectively are called "biomass." Ethanol contains the same chemical compound (C_2H_5OH) found in alcoholic beverages.

Item	Pro	Con
E10 (10% ethanol)	• Nearly 1/2 of U.S. gasoline now contains up to 10% ethanol (E10) to boost octane or meet air quality requirements • Used as an Octane booster	• Uses MTBE, which contaminates water • Less efficient than straight gasoline
E15-E20 (15-20% ethanol)	Intermediate blends can be used today in flexible fuel vehicles	• Cannot be used legally in standard (non-flexible fuel) vehicles • Awaiting EPA approval for a waiver to the Clean Air Act, classifying the blends as "substantially similar" to gasoline
E85 (15% gasoline)	• Enables FFV to operate normally under cold conditions; fueling a vehicle with pure ethanol	• E85-100 creates problems during cold-weather operation • Price is too high

Item	Pro	Con
		• Low energy density

- **FISCHER-TROPSCH DIESEL** - Fischer-Tropsch (F-T) diesel is synthetic diesel fuel produced by converting gaseous hydrocarbons, such as natural gas and gasified coal or biomass, into liquid fuel. TARDEC is currently testing F-T for tactical vehicle use.

Item	Pro	Con
Fischer-Tropsch Diesel	• Can be substituted for diesel in diesel powered vehicles • Provides similar or better vehicle performance than conventional diesel • Cleaner-burning than traditional hydrocarbon fuels • Almost any biomass can be used as a feedstock, such as woody and grassy materials and residues from agriculture and forestry • Liquids produced from the syngas are very clean, sulphur free, and can be converted to automotive fuels • Similar to fossil diesel with regard to energy content, density, and viscosity • Can be blended with fossil diesel in any proportion without engine or infrastructure modifications • More favorable than fossil fuel (higher cetane number, lower aromatic content, and lower NOx and particle emissions)	• Making F-T is a complicated three-step process • Small biomass particles can clog feeder lines • Not widely available • Expensive

- **HYDROGEN -** Hydrogen has the potential to revolutionize transportation and, possibly, our entire energy system. The simplest and most abundant element in the universe, hydrogen can be produced from fossil fuels and biomass and even by electrolyzing water. Producing hydrogen with renewable energy and using it in fuel cell vehicles holds the promise of virtually pollution-free transportation and independence from imported petroleum.

Item	Pro	Con
Hydrogen	• No greenhouse gases are generated • 14 times lighter than air, so transportation costs reduced • Non-toxic • Hydrogen engines last longer than liquid petroleum engines, and start in any weather condition • Fuel spills rapidly evaporate	• Expensive to produce and store • Difficult to generate, handle, and store, requiring bulky and heavy tanks • Depletes atmospheric oxygen • Extremely flammable

• **HYDROGENATION -** (Derived renewable diesel) – Hydrogenaterated Renewable Jet or Diesel Fuel derived renewable diesel (HRD) is the product of fats or vegetable oils—alone or blended with petroleum—that have been refined in an oil refinery. HRD produced in this manner is sometimes called a "second-generation bio-diesel."

Item	Pro	Con
Hydrogenation (HRD)	• Can be produced domestically • Very low sulfur content	• Not widely available • Largely unproven • 30% increase in fuel weight/volume

• **HYTHANE®** - Hydrogen and natural gas/methane blended to create cleaner-burning CNG.

Item	Pro	Con
Hythane®	• Yield the greatest emission reduction benefits while remaining a cost-effective option • Existing refueling compressors, storage tanks, and fuel dispensers can be used	• New technology • Hydrogen is expensive to produce

• **LIQUEFIED NATURAL GAS (LNG) -** To produce LNG, natural gas is purified and condensed into liquid by cooling to -260°F (-162°C). At atmospheric pressure, LNG occupies only 1/600 the volume of natural gas in vapor form. A Gallon Gas Equivalent (GGE) equals about 1.5 gallons of LNG. Because it must be kept at such cold temperatures, LNG is stored in double-wall, vacuum-insulated pressure vessels. LNG fuel systems typically are only used with heavy-duty vehicles.

Item	Pro	Con
Liquefied Natural Gas (LNG)	• Compared to CNG, maximum traveling distance of LNG vehicles is greater and comparable to vehicles powered by traditional fuels • the energy contained in 1 liter of diesel fuel corresponds to 1.7 liters of LNG • Highly clean fuel with minimal harmful emissions • Provides energy with a high density (comparable to oil products) • Does not require a heavy fuel tank • Filling time is comparable to traditional fuels • Offers safer operation (LNG has a higher ignition temperature than gasoline) • Require a smaller gas tank than CNG, increasing the trunk space of	• • LNG must be stored under a very low temperature • • LNG evaporates if a vehicle is not used for a protracted period of time • The technology is more complicated and costly compared to CNG • The filling technology is different and involves new risks

	a vehicle	

- **METHANOL** - Methanol (CH_3OH), also known as wood alcohol, is considered an alternative fuel under the Energy Policy Act of 1992. Methanol can be used to make methyl tertiary-butyl ether (MTBE), oxygenate that is blended with gasoline to enhance octane and create cleaner burning fuel.

Item	Pro	Con
Methanol	• Low production cost • Lower risk of flammability • Manufactured from a variety of carbon-based feed-stocks • Less toxic, and not carcinogenic	• More corrosive than gasoline

- **NANO FUEL TECHNOLOGY** - Nano Fuel Technology can be applied to all fuel powered vehicles, equipment and machinery. Nano Fuel Technology uses nano technology to change the physical properties of the fuel creating a more complete burn.

Item	Pro	Con
Nano Fuel Technology	• Increases fuel efficiency • Reduces emissions • Reduces engine noise • Reduces carbon deposits	• Costs of production • Environmental concerns not known

- **PROPANE** - Propane is sometimes referred to as Liquefied Petroleum Gas, or LPG. It is made from petroleum refining and natural gas processing. Propane is normally a gas, but it is stored in liquid form on a vehicle. Once the propane enters the engine, it becomes a gas again, which helps this fuel to burn so cleanly. The propane fuel grade used in vehicles is called HD-5 and is the third most used fuel behind gasoline and diesel.

Item	Pro	Con
Propane	• Lower emissions • Propane's octane rating is 104 • Burns cleaner • Longer engine life • Lower operating and maintenance costs than gasoline	• Highly flammable • Requires puncture-resistant container

- **P-SERIES** - P-Series fuel is a blend of natural gas liquids (pentanes plus), ethanol, and the biomass-derived co-solvent methyltetrahydrofuran (MeTHF). P-Series fuels are clear, colorless, 89-93 octane, liquid blends that are formulated to be used in flexible fuel vehicles (FFVs).

Item	Pro	Con
P-Series	• P-Series is the only fuel to be added to the list of authorized alternative fuels under the Energy Policy Act of 1992 (EPAct). • Lower emissions	• Not being produced in large quantities • Can only be used in Flex-Fuel vehicles.

Power Sources

The list below is power options that are emerging within the U.S. with the potential to reduce our dependency on foreign oil.

- **Coal –** Coal is a fossil fuel composed mostly of carbon, with traces of hydrogen, nitrogen, sulphur and other elements. Coal is our most abundant fossil fuel resource.

Item	Pro	Con
Coal	• Large domestic coal reserves • Electric power by product • Large amount of energy in a relatively small area compared to most renewable power sources • CO_2 can be sequestrated so it is not released into the atmosphere for a long period of time	• CO_2 & criteria pollutants emissions • Social resistance to coal use • Not sustainable • Uses about 450,000 gallons of fresh water for each GWH of electricity produced • Mining coal is destructive • Large quantities of waste ash must be disposed of • Coal-fired power stations must be large enough to produce adequate power. As such, they are vulnerable to attack.

- **FUEL CELL** - Fuel cells are classified primarily by the kind of electrolyte they employ. This determines the kind of chemical reactions that take place in the cell, the kind of catalysts required, the temperature range in which the cell operates, the fuel required, and other factors. These characteristics, in turn, affect the applications for which these cells are most suitable. There are several types of fuel cells currently under development, each with its own advantages, limitations, and potential applications.

Item	Pro	Con
Fuel Cell Technology	• Fuel cells are energy-efficient, clean, and fuel-flexible • Hydrogen or any hydrogen-rich fuel can be used by this emerging technology • Produces own electricity	• Expensive catalysts • High sensitivity to fuel impurities • Low temperature waste heat and waste heat temperature not suitable for combined heat and power

Item	Pro	Con
Polymer Electrolyte Membrane (PEM)	• Offers a high power density • Low weight and volume compared to other fuel cells. • Only needs hydrogen, oxygen and water to operate • Start quickly	• Must store hydrogen or use a fuel processor to convert methanol to hydrogen, increasing cost and maintenance requirements • Fuel processor emits greenhouse gases
Direct Methanol Fuel Cell (DMFC)	• Do not have fuel storage problems • Powered by pure hydrogen	• Relatively new compared to other fuel cells • R&D 3-4 years behind other fuels
Alkaline Fuel Cell (AFC)	• Produce potable water, heat, and electricity • Among the most efficient fuel cells	• Very susceptible to contamination • Requires pure hydrogen and oxygen • Very expensive
Phosphoric Acid Fuel Cell (PAFC)	• Most mature cell type • First to be used commercially • Has over 200 units in use • Has been used to power large vehicles, i.e. city buses • Only needs hydrogen, oxygen and water to operated	• Not affected by impurities in the hydrogen stream • Requires platinum catalyst • Phosphoric acid becomes a solid at 104°F, making startup difficult and reducing efficiency • Expensive • Typically used for stationary power
Molten Carbonate Fuel Cell (MCFC)	• Non-precious metals can be used as catalysts • More efficient than PAFC • Do not require external fuel processors, as fuels are reformed to hydrogen within the fuel cell	• Not durable • Accelerated component breakdown and corrosion. • Short cell life • Operate at temperatures around 1,200°F
Solid Oxide Fuel Cell **(SOFC)**	• Cells do not have to be constructed in the plate-like configuration • Captures and utilizes system's waste heat • Using Co-generation efficiencies could make it 80-85 percent efficient	• High-temperature operation has disadvantages • Slow startup • Requires significant thermal shielding to retain heat • Has safety issues • Around 50-60% efficient at converting fuel to electricity

Item	Pro	Con
Regenerative Fuel Cell	Produce electricity from hydrogen and oxygen and byproducts are heat and water	Technology is in its infancy

- **NUCLEAR ENERGY** - Nuclear power has developed as an alternative to the traditional fossil fuels of oil, natural gas and coal.

Item	Pro	Con
Nuclear Energy	• Nuclear power plant can generate a great deal of electricity without producing toxic emissions	• Nuclear plants produce radioactive waste, and the danger of nuclear reactor problems can be severe, so the environmental benefits of nuclear are still being debated

- **SOLAR POWER** - Solar energy is energy from the sun in the form of heat and light. Solar energy technologies harness the sun's heat and light for practical ends such as heating, lighting and electricity. Scientists at the Toin University of Yokohama, Japan, have designed a single, compact device that can both convert solar energy to electricity and store the electricity.

Item	Pro	Con
Solar Power	• No emissions • Less maintenance required • No pollution • Renewable at operating site • Sustainable • Heat energy can be stored and used to generate electricity even when it is dark or overcast	• Limited application • Requires large area for substantial power generation • Expensive relative to fossil fuels • Requires large quantities of cooling water • Requires constant adjustment to align with the sun's position in the sky • Very little electricity can be produced when the sun is not shining

Appendix B: Alternate Fuel Vehicles and Equipment

Item	Description
Advanced Technology Vehicle (ATV)	A vehicle that combines new engine/power/drive train systems to significantly improve fuel economy. This includes hybrid power systems and fuel cells, as well as some specialized electric vehicles.
Alternative Fuel Vehicle (AFV)	As defined by the Energy Policy Act, any dedicated, flexible-fuel, or dual-fuel vehicle designed to operate on at least one alternative fuel.
Bi-Fuel Vehicle	A vehicle with two separate fuel systems designed to run on either an alternative fuel, or gasoline or diesel, using only one fuel at a time. Bi-fuel vehicles are referred to as "dual-fuel" vehicles in the Clean Air Act Amendments and Energy Policy Act.
Clean Fuel Vehicle (CFV)	Any vehicle certified by EPA as meeting certain federal emissions standards. The three categories of federal CFV standards from least to most stringent are low emission vehicles (LEV), ultra-low emission vehicles (ULEV), and zero emission vehicles (ZEV). The inherently low emission vehicle (ILEV) standard is voluntary and does not need to be adopted by states as part of the Clean-Fuel Fleet Program. CFV are eligible for two federal programs, the California Pilot Program and the Clean-Fuel Fleet Program. CFV exhaust emissions standards for light-duty vehicles and light-duty trucks are numerically similar to those of CARB (California Low-Emission Vehicle Program).
Converted or Conversion Vehicle	A vehicle originally designed to operate on gasoline or diesel that has been modified or altered to run on an alternative fuel.
Dedicated Natural Gas Vehicle	A vehicle that operates only on natural gas. Such a vehicle is incapable of running on any other fuel.
Dedicated Vehicle	A vehicle that operates solely on one fuel. Generally, dedicated vehicles have superior emissions and performance results because their design has been optimized for operation on a single fuel.
Dual-Fuel Vehicle	Vehicle designed to operate on a combination of an alternative fuel and a conventional fuel. This includes (a) vehicles that use a mixture of gasoline or diesel and an alternative fuel in one fuel tank, commonly called flexible-fuel vehicles; and (b) vehicles capable of operating either on an alternative fuel, a conventional fuel, or both, simultaneously using two fuel systems. They are commonly called bi-fuel vehicles.
Electric Vehicle (EV)	A vehicle powered by electricity, generally provided by batteries. EVs qualify in the zero emission vehicles (ZEV) categories for emissions.
Fuel Improvement Device (FID)	A device to improve fuel efficiency and reduce emissions by creating a more complete burn.

Item	Description
Flexible-Fuel Vehicle (FFV)	A Vehicle with a common fuel tank designed to run on varying blends of unleaded gasoline with either ethanol or methanol.
Hybrid Electric Vehicle (HEV)	A vehicle powered by two or more energy sources, one of which is electricity. HEVs may combine the engine and fuel of a conventional vehicle with the batteries and electric motor of an electric vehicle in a single drive train.
Nano Technology	EPS Nano Fuel Technology uses Nano technology to change the physical properties of the fuel. It is a unique process that takes normal fuel molecules (usually 300 nanometers or larger) and breaks them down into much smaller fuel molecules (usually 3 nanometers or less). EPS Nano Fuel Technology can be applied to all fuel powered vehicles, equipment and machinery.
Vehicle Conversion	Retrofitting a vehicle engine to run on an alternative fuel.
Zero Emission Vehicle (ZEV)	A vehicle that emits no tailpipe exhausts emissions. ZEV credits can be banked within the Consolidated Metropolitan Statistical Area.

Appendix C: Metric Matrix

OBJECTIVES	RESPONSIBLE AGENCY/SYSTEM	KEY PERFORMANCE INDICATOR	METRIC	TIME FRAME	GOAL
Develop Fuel Efficient Engines	Existing Platforms	Burn rate/mpg	Plus or Minus vs Baseline	N/M/F	1,2,3,4,6
Develop Fleet Management Program	Commands	Efficiencies in planning/coordinating	Plus or Minus miles/hrs vs Baseline	N/M	1,2,4,6
Develop Energy Awareness Program	All Levels of Command	Develop and train energy awareness program	% Personnel Trained	N/M/F	1,2,4,6
Pursue Development of Simulators	All Brigade and Above Level Commands	Develop individual training plans and FTXs	# Vehicles vs Baseline	N/M/F	1,2,6
Develop Fleet Maintenance Program	All Levels of Command	Develop operator/organizational maintenance checklist	Baseline vs Change	N/M/F	1,2,6
Develop Weight Reduction Program for Tactical Vehicles	Combat/Materiel Developers	Use next generation materiels (advanced aluminum composites, novel magnesium alloys, and organic composites)	Baseline vs Change	M/F	1,2,4,6
Pursue Alternative Energy Production	TARDEC	Determine if meets established standards	Go/No Go	N/M/F	1,3
Develop Alternative Fuels/Energy	Platform Capabilities	Equal or exceeds current capabilities	Go/No Go	M/F	1,3,4,6
Develop Intelligent Power Distribution Systems	All Levels of Command	Establish grid for power throughout unit's operational area	Baseline vs Change	N/M/F	1,2,4,5
Enforce/Implement Single Fuel on the Battlefield	All Levels of Command	All new equipment must use JP8 or equivalent or alternative energy.	JP8 Fuel Equivalent or Alternative Energy	M/F	2,3,4,5,6
Develop a Comprehensive Fuel/Energy Accountability and Management System	All Levels of Command	Meter and account for all fuel transactions down to user level	% of Fuel Consumers Monitored	M/F	1,2,3,4,5,6
Develop Fuel Efficiency Standards	Hybrid	Combination of battery/motor	Baseline vs Change	M/F	1,2,4,6
Pursue the Development of Alternative Energy Sources	Fuel Cells	Fuel Cell (hydrogen)	Baseline vs Change	F	1,2,3,4,6

LEGEND: Time Frame

Near (N) Term – 2009 - 2015
Mid (M) Term – 2015 - 2025
Far (F) Term – 2025 and Beyond

APPENDIX D: Acronyms and Abbreviations

AC	Alternating Current
AESIS	Army Energy Security Implementation Strategy
AF	Air Force
AFC	Alkaline Fuel Cell
AFSS	Automated Fuel Service Station
AIS	Automated Information System
AMFEC	Army Mobility Fuels and Energy Council
APC	Armored Personnel Carrier
APU	Auxiliary Power Unit
AQI	Air Quality Index
AT&L	Acquisition, Technology and Logistics
AVGAS	Aviation Gas
B20	Biodiesel
B100	Biodiesel
BSM	Business Systems Modernization
BTU	British Thermal Unit
C_2H_5OH	Ethanol
CARB	California Air Resources Board
CASCOM	Combined Arms Support Command
CDD	Concepts and Doctrine Directorate
CFC	Chlorofluorocarbon
CFV	Clean Fuel Vehicle
CH_4	Methane
cm	Centimeter
CNG	Compressed Natural Gas
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CONOPS	Concept of Operations
CONUS	Continental United States
COTS	Commercial Off-the-Shelf
CY	Calendar Year
DA	Department of Army
DC	Direct Current
DESC	Defense Energy Support Center
DFAS	Defense Finance & Accounting Service
DFSP	Defense Fuel Supply Points
DLA	Defense Logistics Agency
DoD	Department of Defense
DODAAC	Department of Defense Activity Address Code
DoE	Department of Energy
DOTMLPF	Doctrine, Organization, Training, Materiel, Leadership and Education, Personnel and Facilities
DSB	Defense Science Board
DU	Dobson Unit
Dv	Deciview
E10	Ethanol
E15-20	Ethanol
E85	Ethanol
EDI	Electronic Data Interchange
EIA	Energy Information Agency
EPA	U.S. Environmental Protection Agency
ESSP	Energy Strategic Security Plan
EV	Electric Vehicle
FAME	Fatty Acid Methyl Ester

FAS	Fuels Automated System
FBCF	Fully Burdened Cost of Fuel
FCC	Fuels Control Center
FCCC	Framework Convention on Climate Change
FCS	Future Combat System
FFV	Flexible Fuel Vehicle
FID	Fuel Improvement Device
FM	Fuels Manager
FNA	Functional Need Analysis
FOB	Forward Operating Base
FT	Fischer-Tropsch
FTX	Field Training Exercise
GGE	Gallon Gas Equivalent
GHG	Green House Gas
H_2	Hydrogen Gas
H_2O	Water
HDRD	Hydrogenation
HEV	Hybrid Electric Vehicle
HEMTT	Heavy Expanded Mobility Tactical Truck
HMMWV	High Mobility Multipurpose Wheeled Vehicle
IAEA	International Atomic Energy Agency
IPDS	Inland Petroleum Distribution System
IQ	Intelligence Quotient
JP8	Jet Propellant Kerosene Fuel
Kg	Kilogram
km	Kilometer
kW	Kilowatt
kWh	Kilowatt Hour
LEV	Low Emission Vehicle
LNG	Liquefied Natural Gas
LOGCAP	Logistics Civil Augmentation Program
LPG	Liquefied Petroleum Gas
M85	Methanol
MCFC	Molten Carbonate Fuel Cell
MeTHF	Methyltetrahydrofuran
MFS	Modular Fuel System
MILSVCS	Military Services
MJ	Megajoule
MLRS	Multiple Launch Rocket System
MOS	Military Occupation Specialty
MTBE	Methyl Tertiary Butyl Ether
MW	Megawatt
NASA	National Aeronautics and Space Administration
NATO	North Atlantic Treaty Organization
NO_2, NOx	Nitrogen Dioxide, Nitrogen Oxides
NO	Nitric Oxide
NO_2	Nitrogen Dioxide
NOAA	National Oceanic and Atmospheric Administration
NO_X	Nitrogen Oxide
NTV	Non-Tactical Vehicle
O_3	Ozone
OAQPS	Office of Air Quality Planning and Standards
OCONUS	Outside the Continental United States
OEF	Operation Enduring Freedom
OIF	Operation Iraqi Freedom
OSD	Office of the Secretary of Defense
OSMIS	Operating and Support Management Information System

PADD	Petroleum Administration for Defense District
PAFC	Phosphoric Acid Fuel Cell
PB	Lead
PCG	Plasma Converted Gas
PEM	Polymer Electrolyte Membrane
PHEV	Plug-In Hybrid Electric Vehicle
PLS	Palletized Load System
PM10, PM2.5	Particulate Matter (10 pm or less, 2.5 pm or less in diameter)
POC	Point of Contact
POP	Persistent Organic Pollutant
POS	Peacetime Operating Stocks
PPM	Parts Per Million
PWRMS	Prepositioned War Reserve Material Stocks
R&D	Research & Development
RIFTS	Rapidly Installed Fluid Transfer System
RV	Recreational Vehicle
SASOL	South African Synthetic Oils
SEC	Senior Energy Council
SME	Subject Matter Expert
SO_2, SOx	Sulfur Dioxide, Sulfur Oxide
SOF	Special Operations Forces
SOFC	Solid Oxide Fuel Cell
TAG	Trigliceride
TARDEC	Tank Automotive Research & Development Center
TBTU	Tera British Thermal Unit
TOE	Table of Organization & Equipment
TRADOC	Training and Doctrine Command
TTP	Techniques, Tactics, and Procedures
TWV	Tactical Wheeled Vehicle
U.S.	United States
ULCANS	Ultra Lightweight Camouflage and Netting System
USACASCOM	U.S. Army Combined Arms Support Command
USD	Undersecretary of Defense
UV	Ultraviolet
VCJCS	Vice Chairman, Joint Chiefs of Staff
VOC	Volatile Organic Compound
WWII	World War II
ZEV	Zero Emission Vehicle

Appendix E: Terms and Definitions

Barrel
A unit of volume equal to 42 U.S. gallons.

Carbon monoxide (CO)
Carbon monoxide is a colorless, odorless gas that is formed when carbon in fuel is not burned completely. It is a component of motor vehicle exhaust, which contributes about 56% of all CO emissions nationwide. Other non-road engines and vehicles (such as construction equipment and boats) contribute about 22% of all CO emissions nationwide. Higher levels of CO generally occur in areas with heavy traffic congestion. In cities, 85 to 95% of all CO emissions may come from motor vehicle exhaust. Other sources of CO emissions include industrial processes (such as metals processing and chemical manufacturing), residential wood burning, and natural sources such as forest fires. Woodstoves, gas stoves, cigarette smoke, and unvented gas and kerosene space heaters are sources of CO indoors. The highest levels of CO in the outside air typically occur during the colder months of the year when inversion conditions are more frequent. The air pollution becomes trapped near the ground beneath a layer of warm air.

Carbon Dioxide (CO_2)
Carbon dioxide is a chemical compound composed of two oxygen atoms covalently bonded to a single carbon atom. It is a gas at standard temperature and pressure. Carbon exists in earth's atmosphere currently at a globally averaged concentration of approximately 385 parts per million by volume after removal of water vapors. Remove one oxygen atom and one has CO – then mix CO with hydrogen and pass the mixture over a catalyst and one has liquid hydrocarbon fuel. This reaction is the Fischer-Tropsch process.

Catalyst Coke
Catalyst coke is coke that has deposited on the catalysts used in oil refining, such as those in a fluid catalytic cracker. This coke is impure and is only used for fuel.

Coal
Coal is a readily combustible black or brownish-black rock. It is composed primarily of carbon and hydrogen along with small quantities of other elements, notably sulfur. Coal is extracted from the ground by coal mining, either underground mining or open pit mining (surface mining).
Coal is the largest source of fuel for the generation of electricity worldwide, as well as the largest worldwide source of carbon dioxide emissions.

Crude Oil
Crude oil is a mixture of hydrocarbons that exists in liquid phase in natural underground reservoirs and remains liquid at atmospheric pressure after passing through surface separating facilities. Depending upon the characteristics of the crude stream, it may also include small amounts of hydrocarbons that exist in gaseous phase in natural underground reservoirs but are liquid at atmospheric pressure after being recovered from oil well (casinghead) gas in lease separators and are subsequently commingled with the crude stream without being separately measured. Lease condensate recovered as a liquid from natural gas wells in lease or field separation facilities and later mixed into the crude stream is also included; small amounts of nonhydrocarbons produced with the oil, such as sulfur and various metals; drip gases, and liquid hydrocarbons produced from tar sands, oil sands, Gilsonite, and oil shale. Liquids produced at natural gas processing plants are excluded. Crude oil is refined to produce a wide array of petroleum products, including heating oils; gasoline, diesel and jet fuels; lubricants; asphalt; ethane, propane, and butane; and many other products used for their energy or chemical content.

Distillate Fuel Oil
A general classification for one of the petroleum fractions produced in conventional distillation operations. It includes diesel fuels and fuel oils. Products known as No. 1, No. 2, and No. 4 diesel fuel are used in on-highway diesel engines, such as those in trucks and automobiles, as well as off-highway engines, such as those in railroad locomotives and agricultural machinery. Products known as No. 1, No. 2, and No. 4 fuel oils are used primarily for space heating and electric power generation

Electricity (Purchased)
Electricity purchased for refinery operations that is not produced within the refinery complex.

E85
E85 is a blend of 85% ethanol and 15% gasoline. It is the most commonly available blended fuel for use in flex-fuel vehicles (FFVs).

Lead
Lead is a metal found naturally in the environment as well as in manufactured products. The major sources of lead emissions have historically been motor vehicles (such as cars and trucks) and industrial sources. As a result of EPA's regulatory efforts to remove lead from gasoline, emissions of lead from the transportation sector dramatically declined by 95% between 1980 and 1999, and levels of lead in the air decreased by 94% between 1980 and 1999. Today, the highest levels of lead in air are usually found near lead smelters. Other stationary sources are waste incinerators, utilities, and lead-acid battery manufacturers.

Liquefied Petroleum Gases (LPG)
Liquefied Petroleum Gases are a group of hydrocarbon-based gases derived from crude oil refining or natural gas fractionation. They include: ethane, ethylene, propane, propylene, normal butane, butylene, isobutene, and isobutylene. For convenience of transportation, these gases are liquefied through pressurization.

Marketable Coke
Marketable Coke is coke that is relatively pure carbon and can be sold fur use as fuel (i.e. fuel grade coke), or for the manufacture of dry cells, electrodes (i.e. anode grade coke).

Methanol
Methanol is a colorless, odorless and nearly tasteless alcohol with the simplest chemical structure of all the alcohols.

Natural Gas
Natural Gas is a gaseous mixture of hydrocarbon compounds, the primary one being methane.

Nitrogen Oxides
Nitrogen Oxides is the generic term for a group of highly reactive gases, all of which contain nitrogen and oxygen in varying amounts. Many of the nitrogen oxides are colorless and odorless. However, one common pollutant, nitrogen dioxide (NO_2) along with particles in the air can often be seen as a reddish-brown layer over many urban areas.

Other Petroleum Products
Other petroleum products includes pentanes plus, other hydrocarbons, oxygenates, hydrogen, unfinished oils, gasoline, special naphthas, jet fuel, lubricants, asphalt and road oil, and miscellaneous products.

Ozone
The ozone is a gas composed of three oxygen atoms. It is not usually emitted directly into the air, but at ground-level is created by a chemical reaction between oxides of nitrogen (NOx) and volatile organic compounds (VOC) in the presence of sunlight. Ozone has the same chemical structure whether it occurs miles above the earth or at ground-level and can be "good" or "bad," depending on its location in the atmosphere. In the earth's lower atmosphere, ground-level ozone is considered "bad." Motor vehicle exhaust and industrial emissions, gasoline vapors, and chemical solvents as well as natural sources emit NOx and VOC that help form ozone. Ground-level ozone is the primary constituent of smog. Sunlight and hot weather cause ground-level ozone to form in harmful concentrations in the air. As a result, it is known as a summertime air pollutant. Many urban areas tend to have high levels of "bad" ozone, but even rural areas are also subject to increased ozone levels because wind carries ozone and pollutants that form it hundreds of miles away from their original sources. “Good” ozone occurs naturally in the stratosphere

approximately 10 to 30 miles above the earth's surface and forms a layer that protects life on earth from the sun's harmful rays.

Particulate Matter
Particulate matter is a mixture of extremely small particles and liquid droplets. Particle pollution is made up of a number of components, including acids (such as nitrates and sulfates), organic chemicals, metals, and soil or dust particles. The size of particles is directly linked to their potential for causing health problems. EPA is concerned about particles that are 10 micrometers in diameter or smaller because those are the particles that generally pass through the throat and nose and enter the lungs. Once inhaled, these particles can affect the heart and lungs and cause serious health effects. EPA groups particle pollution into two categories:

- "Inhalable coarse particles," such as those found near roadways and dusty industries, are larger than 2.5 micrometers and smaller than 10 micrometers in diameter.
- "Fine particles," such as those found in smoke and haze, are 2.5 micrometers in diameter and smaller. These particles can be directly emitted from sources such as forest fires, or they can form when gases emitted from power plants, industries and automobiles react in the air.

Petroleum Administration for Defense (PAD) Districts
The U.S. is divided into 5 Petroleum Administration for Defense Districts, or PADDs. These were created during WWII under the Petroleum Administration for War to help organize the allocation of fuels derived from petroleum products, including gasoline and diesel (or "distillate") fuel. Today, these regions are still used for data collection purposes.

Petroleum Coke
Petroleum coke is a carbonaceous solid derived from oil refinery coder units and other cracking processes. Petroleum coke is high in carbon content and low in hydrogen that is the final product of thermal decomposition in the condensation process in cracking. The conversion is 5 barrels (of 42 U.S. gallons each) per short ton. Coke from petroleum has a heating value of 6.024 million BTU per barrel.

Refinery
A Refinery is composed of a group of chemical engineering unit processes and unit operations used for refining certain materials or converting raw material into products of value.

Residual Fuel Oil
Residual fuel oil is a general classification for the heavier oils, known as No. 5 and No. 6 fuel oils, that remain after the distillate fuel oils and lighter hydrocarbons are distilled away in refinery operations. It conforms to ASTM Specifications D 396 and D 975 and Federal Specification VV-F-815C. No. 5, a residual fuel oil of medium viscosity, is also known as Navy Special and is defined in Military Specification MIL-F-859E, including Amendment 2 (NATO Symbol F-770). It is used in steam-powered vessels in government service and inshore powerplants. No. 6 fuel oil includes Bunker C fuel oil and is used for the production of electric power, space heating, vessel bunkering, and various industrial purposes.

Sulphur Dioxide
Sulphur Dioxide is in the family of sulfur oxide gases (SOx). These gases dissolve easily in water. Sulfur is prevalent in all raw materials, including crude oil, coal, and ore that contains common metals like aluminum, copper, zinc, lead, and iron. SOx gases are formed when fuel containing sulfur, such as coal and oil, is burned, and when gasoline is extracted from oil, or metals are extracted from ore. SO_2 dissolves in water vapor to form acid, and interacts with other gases and particles in the air to form sulfates and other products that can be harmful to people and their environment.

Steam (Purchased)
Steam purchased to be used by a refinery that was not generated from within the refinery complex.

Still Gas

Still gas is any form or mixture of gases produced in refineries by distillation, cracking, reforming, and other processes. The principal constituents are methane, ethane, ethylene, normal butane, butylene, propane, propylene, etc. Still gas is used as a refinery fuel and a petrochemical feedstock. The conversion factor is 6 million BTUs per fuel oil equivalent barrel.

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